ST 11-192

COLOR TELEVISION

U. S. ARMY

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CHAPTER 1

COLOR FUNDAMENTALS AND THE COLOR CAMERA

Section I. INTRODUCTION

1. GENERAL

a. This special text presents information relating to the basic theory and characteristics of color television systems and equipment. Factors affecting the performance of these systems and typical system applications are also discussed. The theory and characteristics of monochrome equipment and systems have been studied in prerequisite subcourses and will be reviewed only when they aid in understanding color television principles.

b. Three basic requirements of a color television system are: (1) the system must be capable of reproducing high-quality images with good color fidelity, (2) the signal produced by the color television system must be capable of producing high-quality black-and-white images on existing black-and-white receivers without requiring modification, and (3) the system must be capable of operating within the present 6-mc broadcast channel.

c. The color camera and receiver must be capable of operating within the confines of certain basic color principles. For this reason, the basic color principles are discussed first.

Section II. BASIC COLOR PRINCIPLES

2. GENERAL

Since the study of color is a complex subject, this discussion will be limited to the facts as they apply to the basic principles of color television. The study of color is the study of vision, that is, the physical reception of light by the human eye and the image that is registered on the brain. Since color first of all depends on light, the nature of light must be examined.

3. THE NATURE OF LIGHT

Light is one of a number of known forms of radiant energy, and it differs only in frequency and wavelength from the other forms. The radiant energy spectrum is shown in figure 1. As an aid in understanding the types of radiant energy, assume that a radio broadcast transmitter has an unlimited variable frequency range. Increasing the transmitting frequency from the radio broadcast range to between 50 mc and 1000 mc brings the transmitter into the television band. Between 1000 mc and 40, 000 mc the transmitter operates in the radar band. If the transmitter could be increased to a frequency above 40, 000 mc, the antenna would start to radiate heat. This is known as infrared radiation, and all common forms of heat fall into this portion of the radiant energy spectrum. If the transmitter is raised above the infrared frequencies, the antenna will radiate light. This is the same kind of light that is given off by the sun or by an electric light bulb, except that it has been produced electronically. If the transmitted frequencies continued to increase beyond the frequencies of light, the antenna would radiate ultra violet rays, x-rays, and gamma rays.

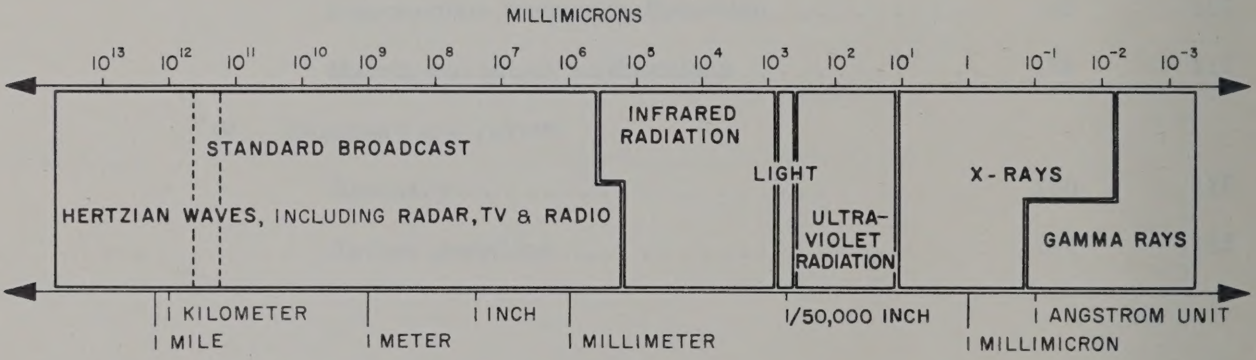

MILLIMICRONS
10^{13} 10^{12} 10^{11} 10^{10} 10^{9} 10^{8} 10^{7} 10^{6} 10^{5} 10^{4} 10^{3} 10^{2} 10^{1} 1 10^{-1} 10^{-2} 10^{-3}
STANDARD BROADCAST
HERTZIAN WAVES, INCLUDING RADAR, TV & RADIO
INFRARED RADIATION
LIGHT
ULTRA-VIOLET RADIATION
X-RAYS
GAMMA RAYS
1 KILOMETER
1 MILE
1 METER
1 INCH
1 MILLIMETER
1/50,000 INCH
1 MILLIMICRON
1 ANGSTROM UNIT

Figure 1. Radiant energy spectrum.

4. WAVELENGTHS AND FREQUENCY

a. The frequencies of light are located in the radiant energy spectrum in a band of wavelengths from 400 to 700 millimicrons. A micron is one-millionth of a meter; therefore, a millimicron is one-billionth of a meter. If these wavelengths of light energy are combined in certain specific quantities, the sensation of white light is produced which is similar to that produced on the screen of a monochrome television receiver.

b. Conversely, white light can be divided into component radiations by passing a narrow beam of light through a glass prism (fig. 2). This produces a band of colored light called the visible spectrum of light. The basic colors are red, orange, yellow, green, cyan, blue, and violet and have wavelengths measured in millimicrons as indicated in figure 2. Various

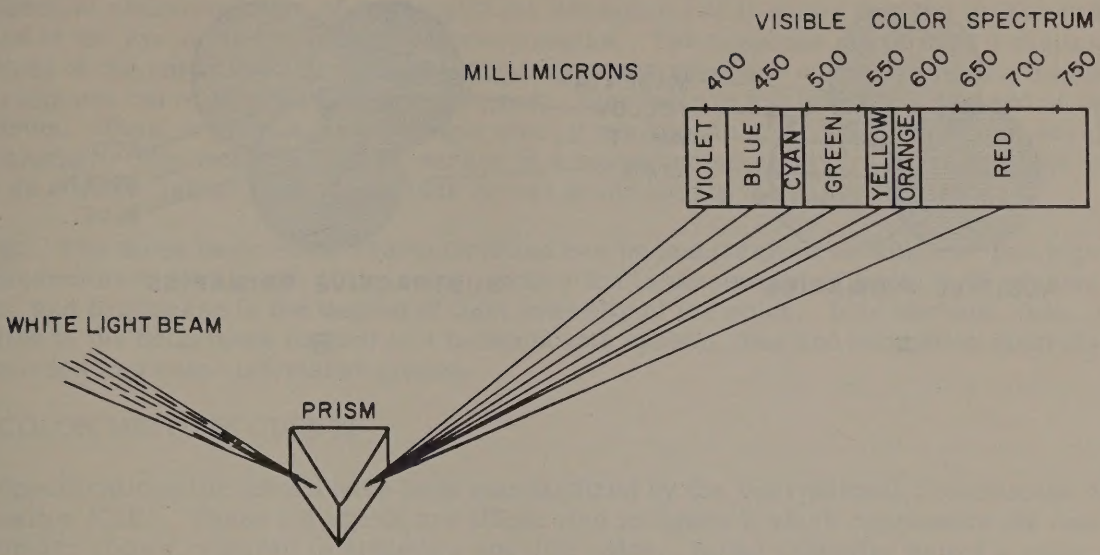


Figure 2. Separation of white light through a prism.

combinations of these basic colors will produce the full range of color sensations.

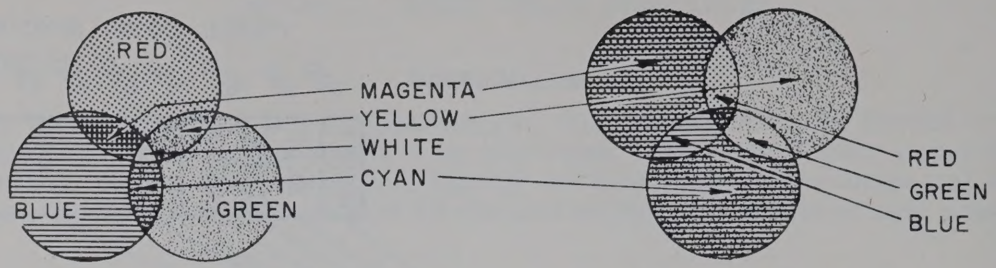
5. ADDITIVE AND SUBTRACTIVE PRIMARIES

a. There are two methods of color mixing, the additive and subtractive. For both methods there are three primary colors. In the subtractive method, the colors magenta, yellow, and cyan shown in figure 3B are the subtractive primaries. In the additive method, the colors red, green, and blue shown in figure 3A are the additive primaries.

b. The subtractive method of color mixing deals with the absorption and reflection of light. For example, if a yellow object is viewed, all of the light that falls on the object is absorbed by it except yellow which is reflected. If yellow and magenta are combined and viewed, all of the light that falls on the color is absorbed except red which is reflected. Thus it is said that combining yellow and magenta produces red as shown in figure 3B. Similarly, other combinations of the subtractive primaries produce various other colors. Combining all three subtractive primaries produces black.

c. The additive method of color mixing, which is used in color television, does not deal with reflection or absorption of light. It deals with the mixing of various colors of light. The colors derived by superimposing combinations of red, green, and blue lights are shown in figure 3C. For example, the combination of red and green light produces yellow light. Combining all three additive primaries produces white light.

d. The additive and subtractive methods of color mixing can be described in a single example. Assume a white light is passed through a red, a green, and a blue filter as shown in figure 3C. The red filter will absorb all colors except red which is transmitted. The green filter will absorb all colors except green which is transmitted. The blue filter will absorb all colors except blue, which is transmitted. If the light attempts to pass through all three filters at one time, the filters will absorb all the light, transmitting none. This describes the absorption characteristic of the subtractive method of color mixing which causes the filters to appear red, green, and blue. Now examine the beams of light that pass through these filters where the red and green light beams are superimposed, the product of the two beams will be a yellow light. Where the red and blue light beams are superimposed, the product of the two beams will be a magenta light. Where the blue and green light beams are superimposed, the

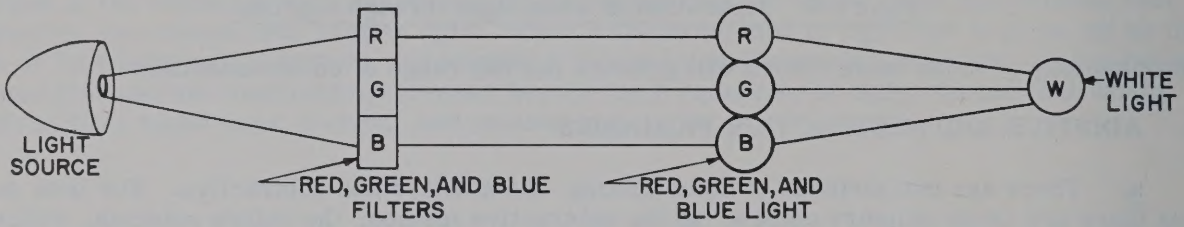


ADDITIVE PRIMARIES

A

SUBTRACTIVE PRIMARIES

B



SUBTRACTIVE AND ADDITIVE COLOR MIXING

C

Figure 3. Additive and subtractive primaries.

product of the two beams will be a cyan light. Where all three light beams are superimposed, the product will be a white light.

6. COLOR CHARACTERISTICS

a. The study of color as it applies to color television would be relatively simple if the only consideration were the colors obtainable by mixing various intensities of red, green, and blue primary lights. These primary colors and those which result from their mixture, such as yellow, orange, magenta, cyan, violet, etc, are factors which cause color sensation, but they contribute only one of three basic characteristics of color sensation, hue. Saturation and brightness must also be considered.

b. Saturation, sometimes called tint, describes the amount of white light mixed with the hue. For example, full saturation of a red hue is the true vivid red without any white light, whereas a pink hue is much less saturated and is actually the red hue with the addition of a large amount of white light. Brightness is the basic characteristic describing the range of a color between light (white) and dark (black). Saturation and brightness are somewhat related because saturation refers to the degree to which a color departs from gray or neutral hue of the same brightness.

c. Figure 4 illustrates the luminosity response of the human eye. This curve measures the spectral characteristics of the brightness sensation and it shows that the brightness response of the eye varies with different wavelengths. The response curve is at a minimum at the start of the color spectrum, so that the brightness response of the eye is at a minimum. The response curve is maximum around green, then falls to a minimum at the end of the color spectrum. Thus, a given amount of light energy can appear much brighter at one wavelength than another. For example, on the screen of a monochrome receiver, a green scene will appear as a much lighter gray than a blue or red scene having the same light energy.

d. The three basic color characteristics can be summarized as follows: hue represents the predominant wavelength of the color, saturation is the amount of white light present in this color, and brightness is the degree of light intensity of the color. It is obvious, then, that in addition to the brightness control of a monochrome system, hue and saturation controls must be included in a color television system.

7. COLOR MIXTURE CURVES

Specifications for colors have been standardized by the International Commission on Illumination (CIE). These standards are illustrated in figure 5 which represents the amounts of primary colors required to achieve a specific color. As an example, select a color which has a wavelength of 560 millimicrons. The amounts of primary colors required to reproduce this color can be found from the color mixture curves; that is, 0.63 red, 0.98 of green, and zero of blue. The information derived from the color-mixture curves can be converted to percentages by using the equations adopted by the CIE:

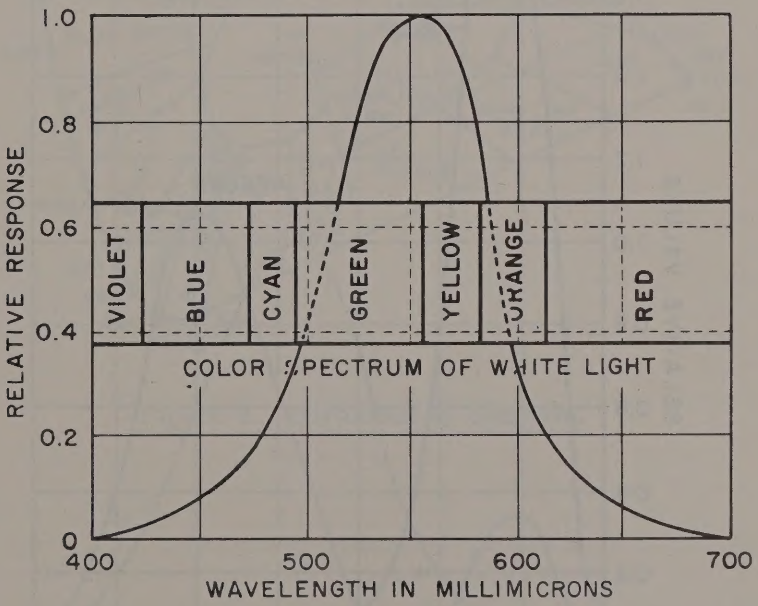


Figure 4. Luminosity response of the human eye.

$$\text{red} = \frac{\text{red}}{\text{red} + \text{green} + \text{blue}}$$

$$\text{green} = \frac{\text{green}}{\text{red} + \text{green} + \text{blue}}$$

$$\text{blue} = \frac{\text{blue}}{\text{red} + \text{green} + \text{blue}}$$

For the values given above, it can be seen that the color which has a wavelength of 560 millimicrons is $\frac{0.63}{0.63+0.98+0}$ or 39.1 percent red, $\frac{0.98}{0.63+0.98+0}$ or 60.9 percent green, and $\frac{0}{0.63+0.98+0}$ or 0 percent blue.

8. CHROMATICITY DIAGRAM

The procedure described in paragraph 7 can be repeated, plotting all of the colors on the chromaticity diagram in figure 6. "Chromaticity" represents hue and saturation. The horseshoe curve is numbered from 400 to 700, representing wavelengths of various colors in millimicrons. The triangle inside the curve depicts the Federal Communications Commission range of all hues and saturations with respect to white. The area outside the triangle represents colors not reproducible by the color television system, but, since they are mostly heavily saturated greens and blues that do not occur in nature, the omission is relatively unimportant. The chromaticity diagram shows approximate color hue areas and aids in color

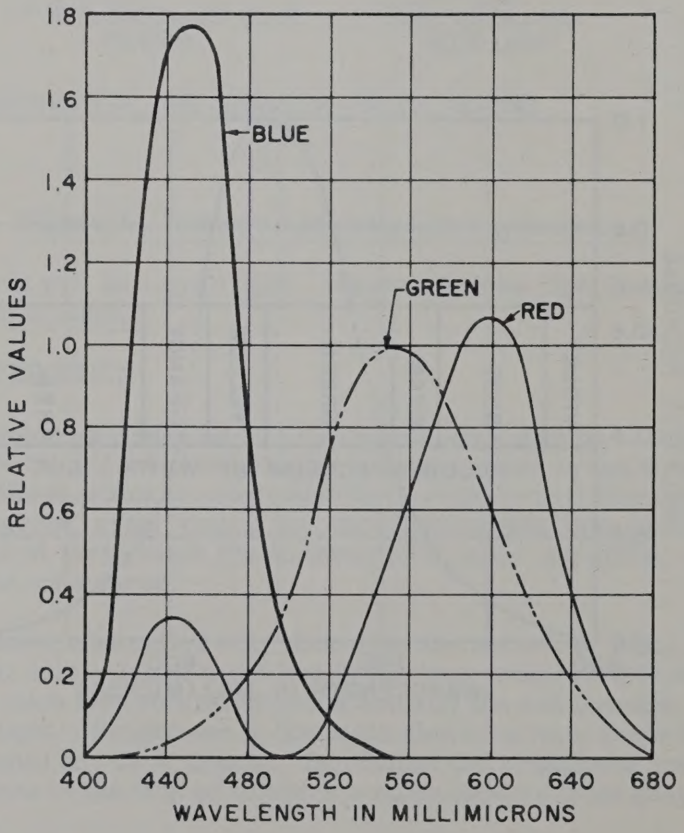
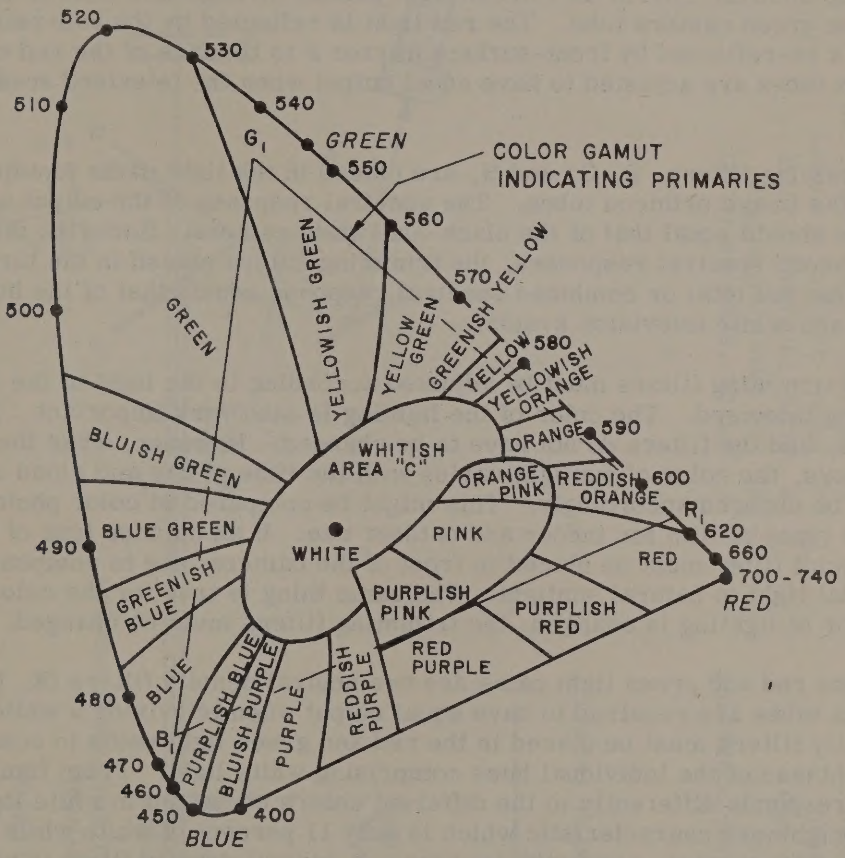


Figure 5. Color mixture curves.

mixing. A straight line drawn between any two points will pass through all of the colors that can be obtained by mixing the colors represented by the two points.

9. COLOR PHENOMENON

It has been found that the normal human eye tends to become color blind to a varying degree as color areas in a color scene become smaller. To the eye, all colors appear to change as the color area becomes smaller. For example, minute yet discernible particles of blue and green alternately spaced will become a solid blue-green as the distance between the colors and the eye increases. For fine detail in a color scene, it is only necessary to convey a brightness variable to represent accurately the eye's interpretation of the scene.



520
530
540
510
G1
GREEN
550
COLOR GAMUT
INDICATING PRIMARIES
560
570
YELLOW
500
GREEN
YELLOWISH GREEN
YELLOW GREEN
GREENISH YELLOW
YELLOW
580
YELLOWISH ORANGE
ORANGE
590
BLUISH GREEN
WHITISH
AREA "C"
ORANGE PINK
REDDISH ORANGE
600
R1
620
BLUE GREEN
WHITE
PINK
660
RED
490
700-740
RED
GREENISH BLUE
PURPLISH PINK
PURPLISH RED
RED PURPLE
BLUE
480
B1
PURPLISH BLUE
BLUISH PURPLE
PURPLE
REDDISH PURPLE
470
460
450
400
BLUE

Figure 6. Chromaticity diagram.

10. THE COLOR TELEVISION CAMERA

a. The color television camera must divide the televised scene into separate red, green, and blue light images. Figure 7 shows an optical system used in a three-tube color television camera. On the turret is an objective lens which is very similar to that used at present in black-and-white cameras. All light enters the center, or objective, lens. Light passes to blue-reflecting dichroic mirror E. A dichroic mirror has the property of passing all light except the light which it is designed to reflect. In this case, the dichroic mirror will pass red and green light and reflect blue light. Blue light is reflected to the face of a front-surface mirror which re-reflects the light, focusing it on the face of an image orthicon tube designed to operate from only the blue light of the televised scene. The red and green light passes to red-reflecting dichroic mirror D. Green light passes through this mirror and is focused on the face of the green camera tube. The red light is reflected by the red-reflecting dichroic mirror and is re-reflected by front-surface mirror J to the face of the red camera tube. The three camera tubes are adjusted to have equal output when the televised scene is white or neutral.

b. Trimming filters, F, G, and H, are placed in the light paths to adjust the spectral response of the image orthicon tubes. The spectral response of the output of the combined camera tubes should equal that of the black-and-white camera. Since the dichroic mirrors have rather broad spectral responses, the trimming filters placed in the three light paths are selected so that the total or combined spectral response equals that of the human eye or that of the black-and-white television system.

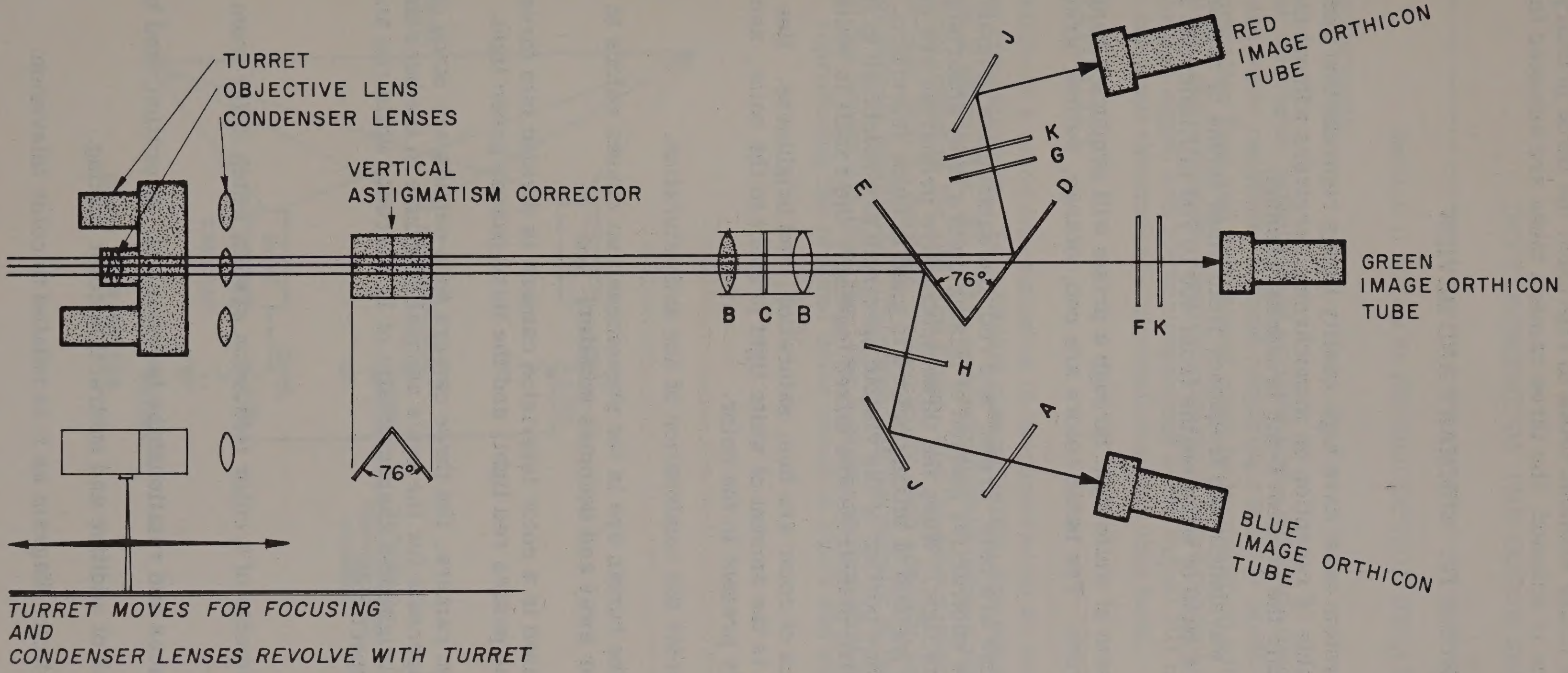
c. The trimming filters must be adjusted according to the light in the room where the scene is being televised. The color of the lighting is also very important. It can be kept constant indoors, and the filters do not have to be changed. However, when the color camera is moved outdoors, the color of sunlight varies with the time of day and cloud conditions, and the filters must be changed accordingly. This might be compared to color photography. There are different types of film for indoor and outdoor use. If an outdoor type of film is used indoors, a special filter must be placed in front of the camera lens to compensate for the change from artificial light to natural sunlight. The same thing is true for the color camera. Each time the color of lighting is changed, the trimming filters must be changed.

d. In the red and green light paths are two neutral density filters (K, fig. 7). Since the three camera tubes are required to have equal output when televising a white or neutral scene, neutral density filters must be placed in the red and green light paths to compensate for the unequal brightness of the individual hues comprising white light. From figure 4 it can be seen that the eye responds differently to the different colors contained in white light. Actually, blue light has a brightness characteristic which is only 11 percent of white while red and green are 30 percent and 59 percent, respectively; hence, a neutral density filter is necessary in the red and green light paths to balance the amount of light focused on the three camera tubes.

e. A vertical astigmatism corrector is required in the main light path because horizontal astigmatism is introduced when light passes through dichroic mirrors. Since blue light does not pass through the dichroic mirror, a horizontal astigmatism corrector (A, fig. 7) is incorporated to balance astigmatically the blue light path with the red and green light paths.

f. A remotely controlled iris (C, fig. 7) is controlled by the operator in the master control room or other convenient location. As the light on the televised scene varies in brightness, the operator may vary the amount of light passing through the color television camera. This is similar to the iris on most cameras.

g. Thus, in the color television camera, the light of the original scene is separated into three primary colors - red, green, and blue. Three individual signals or voltage elements


TURRET
OBJECTIVE LENS
CONDENSER LENSES
VERTICAL ASTIGMATISM CORRECTOR
76°
TURRET MOVES FOR FOCUSING AND CONDENSER LENSES REVOLVE WITH TURRET
B C B
E
D
76°
K
G
J
H
J
A
F K
RED IMAGE ORTHICON TUBE
GREEN IMAGE ORTHICON TUBE
BLUE IMAGE ORTHICON TUBE

LEGEND

A	HORIZONTAL ASTIGMATISM CORRECTOR
B	RELAY LENSES BOTH 9.5" F/4
C	REMOTELY CONTROLLED IRIS
D	RED-REFLECTING DICHROIC
E	BLUE-REFLECTING DICHROIC
F	GREEN TRIMMING FILTER
G	RED TRIMMING FILTER
H	BLUE TRIMMING FILTER
J	FRONT SURFACE MIRRORS
K	NEUTRAL DENSITY FILTERS

Figure 7. Three-tube color television camera optical system.

are provided by means of the image orthicon tubes to represent the three primary colors. When a white or neutral scene is scanned, the three camera tubes are adjusted for equal voltage outputs.

Section IV. SUMMARY AND REVIEW

11. SUMMARY

a. A color television system must have high-quality image reproduction and color fidelity. The signal must be capable of reception on monochrome receivers without modification. The system must operate within the present 6-mc broadcast channel.

b. Light differs only in wavelength and frequency from other forms of radiant energy. Light waves are contained in a band of wavelengths from 400 to 700 millimicrons in the radiant energy spectrum.

c. Passing a narrow beam of white light through a prism will produce a band of colored light called the visible spectrum. The basic colors are red, orange, yellow, green, cyan, blue, and violet.

d. The additive primaries are blue, green, and red; the subtractive primaries are yellow, magenta, and cyan. The subtractive method of mixing colors is by absorbing or subtracting from the spectrum of white light. When the three subtractive primaries are combined, the result is black. The additive method of mixing colors is used in color television. In this method the red, green, and blue portion of the visible spectrum are combined to form new colors. When the three additive primaries are mixed together, the result is white.

e. Three characteristics of color are hue, saturation, and brightness. Hue is the primary color itself, saturation is the amount of white light present in the color, and brightness is the amount of light intensity present in the color.

f. Chromaticity represents the combination of hue and saturation.

g. A characteristic of the human eye is the phenomena that causes colors to blend when a color scene is moved farther away and becomes smaller.

h. The optical system used in a color television camera is divided into three light paths; one path passes blue light, one passes red light, and the third passes green light.

i. In the color television camera, the three camera tube outputs are made equal by using neutral-density filters to compensate for the eye's unequal response to the hues that comprise white light. Blue light has a brightness characteristic of 11 percent, while red and green are 30 percent and 59 percent respectively.

12. REVIEW QUESTIONS

a. Describe the requirements of a color television system which differ from those of a monochrome system.

b. What are the differences and relationships between hue, saturation, and brightness?

c. Explain the processes of additive and subtractive color mixing.

d. Describe the chromaticity diagram as it is related to color television.

e. What are trimming filters used in the color television camera?

CHAPTER 2

DEVELOPMENT OF THE COLOR SIGNAL

Section I. COLOR REPRODUCTION REQUIREMENTS

13. INTRODUCTION

A color television system must provide high-definition black and white pictures for standard black and white receivers without requiring receiver modification. This means that chrominance information (hue and saturation) must be transmitted within the standard 6-mc television channel without disturbing the already existing 4.5-mc monochrome signal. Although the 4.5-mc monochrome signal and the accompanying audio signal fill most of the 6-mc channel, it is possible to transmit chrominance information within this band.

14. COMPATIBILITY

The ability of a color transmission to be received on an unmodified monochrome receiver is known as compatibility. To maintain compatibility, the color camera must produce a black and white or Y signal (fig. 8). This is accomplished using a matrix or mixing technique in which the total output of the red, the green, and the blue camera tubes is reduced to 30 percent, 59 percent, and 11 percent, respectively, and added to produce a monochrome or Y signal with 100 percent amplitude. This matches the outputs of the color camera to the luminosity response of the human eye (fig. 4). The Y signal is then applied directly to the monochrome kinescope, reproducing the original color scene in black and white.

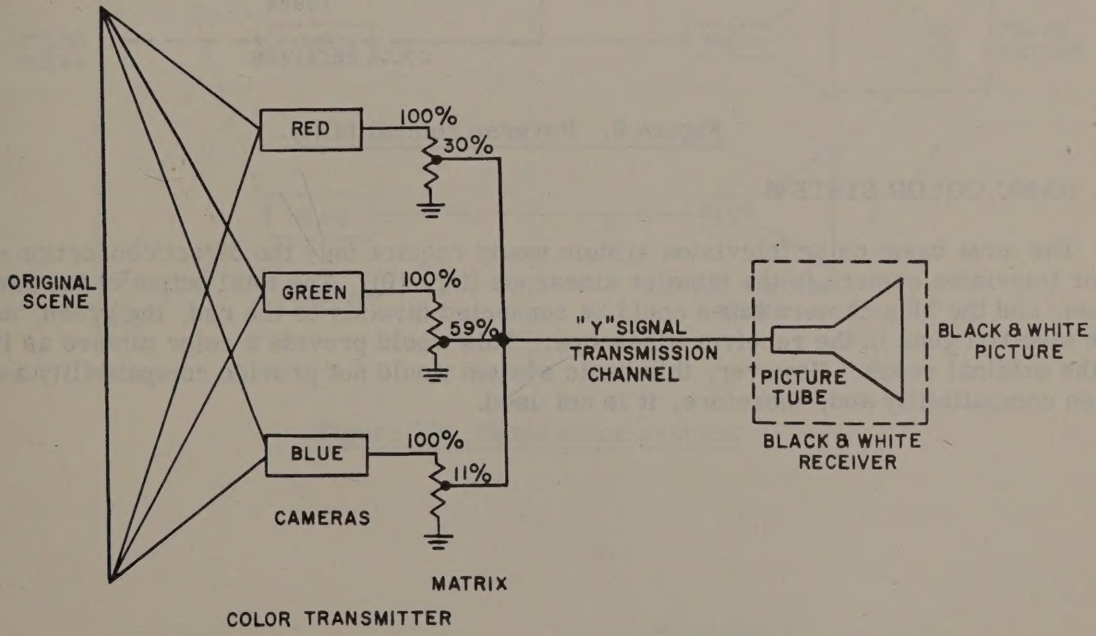

ORIGINAL SCENE
RED
100%
30%
GREEN
100%
59%
BLUE
100%
11%
CAMERAS
MATRIX
COLOR TRANSMITTER
"Y" SIGNAL
TRANSMISSION CHANNEL
PICTURE TUBE
BLACK & WHITE PICTURE
BLACK & WHITE RECEIVER

Figure 8. Compatibility.

15. REVERSE COMPATIBILITY

The ability of a monochrome transmission to be received on a color television receiver is known as reverse compatibility (fig. 9). The Y signal is divided equally three ways in the color television receiver. After the tricolor kinescope is adjusted to produce a white raster, the separated signals are applied through a matrixing circuit to the electron guns which activate phosphors that produce red, green, and blue light. (Hereafter, the electron guns will be designated red, green, or blue, depending upon the color of the phosphor which they activate.) The matrixing circuit reproduces the separated signals in the ratio of 30:59:11 so that 30 percent, 59 percent, and 11 percent of the Y signal amplitude is fed to the red, green and blue electron guns, respectively, in the tricolor kinescope. These outputs superimposed on the face of the color kinescope provide 100 percent amplitude of the Y signal.

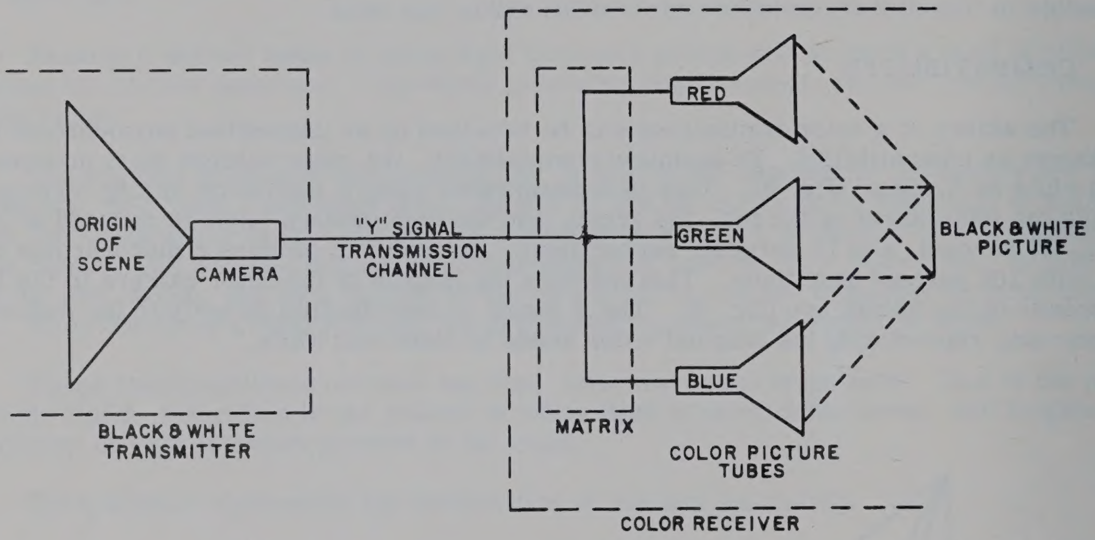


Figure 9. Reverse compatibility.

16. BASIC COLOR SYSTEM

The most basic color television system would require only the direct connection of the color television camera to the tricolor kinescope (fig. 10). The total output of the red, the green, and the blue camera tubes could be connected directly to the red, the green, and the blue electron guns in the receiver kinescope. This would provide a color picture as it appears on the original scene. However, this basic system would not provide compatibility and reverse compatibility and, therefore, it is not used.

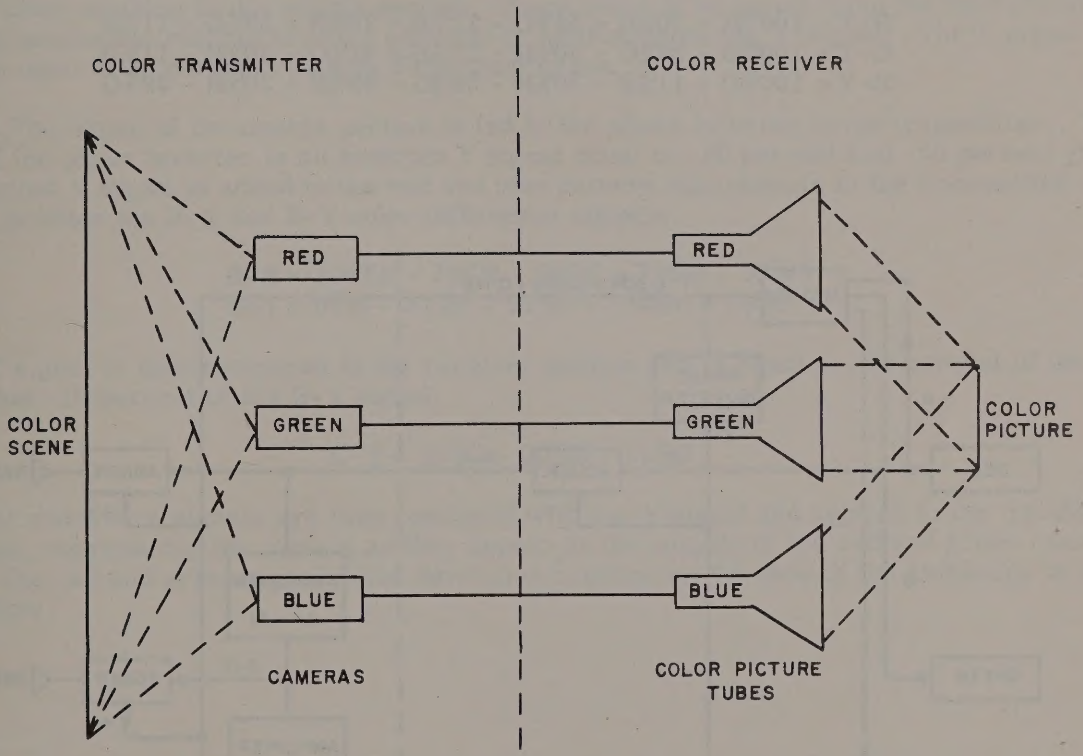

COLOR TRANSMITTER
COLOR RECEIVER
COLOR SCENE
RED
GREEN
BLUE
CAMERAS
RED
GREEN
BLUE
COLOR PICTURE TUBES
COLOR PICTURE

Figure 10. Basic color system.

Section II. CHROMINANCE SIGNAL DEVELOPMENT

17. COLOR DIFFERENCE SIGNALS

a. Since the monochrome receiver is unable to detect the color signals if they are transmitted separately, the color television system must produce a luminance or Y signal which, combined with chrominance information, does not interfere with monochrome reception and yet is detectable by color receivers.

b. The black and white or Y signal is developed in the matrix section of the color transmitter (fig. 11). Chrominance signals can be produced in the transmitter by developing color difference signals. The color difference signal is developed by subtracting the Y signal from the individual camera signals. To do this, the Y signal is inverted so that all values are negative. Since the Y signal comprises 30 percent of the red, 59 percent of the green, and 11 percent of the blue camera tube outputs, the inverted Y signal is equal to -30 percent of the red, -59 percent of the green, and -11 percent of the blue. This is added algebraically to the individual camera tube outputs, producing three chrominance signals.

$$
\begin{aligned}
R-Y &= 100\%R - 30\%R - 59\%G - 11\%B = 70\%R - 59\%G - 11\%B \\
G-Y &= 100\%G - 59\%G - 30\%R - 11\%B = 41\%G - 30\%R - 11\%B \\
B-Y &= 100\%B - 11\%B - 30\%R - 59\%G = 89\%B - 30\%R - 59\%G
\end{aligned}
$$

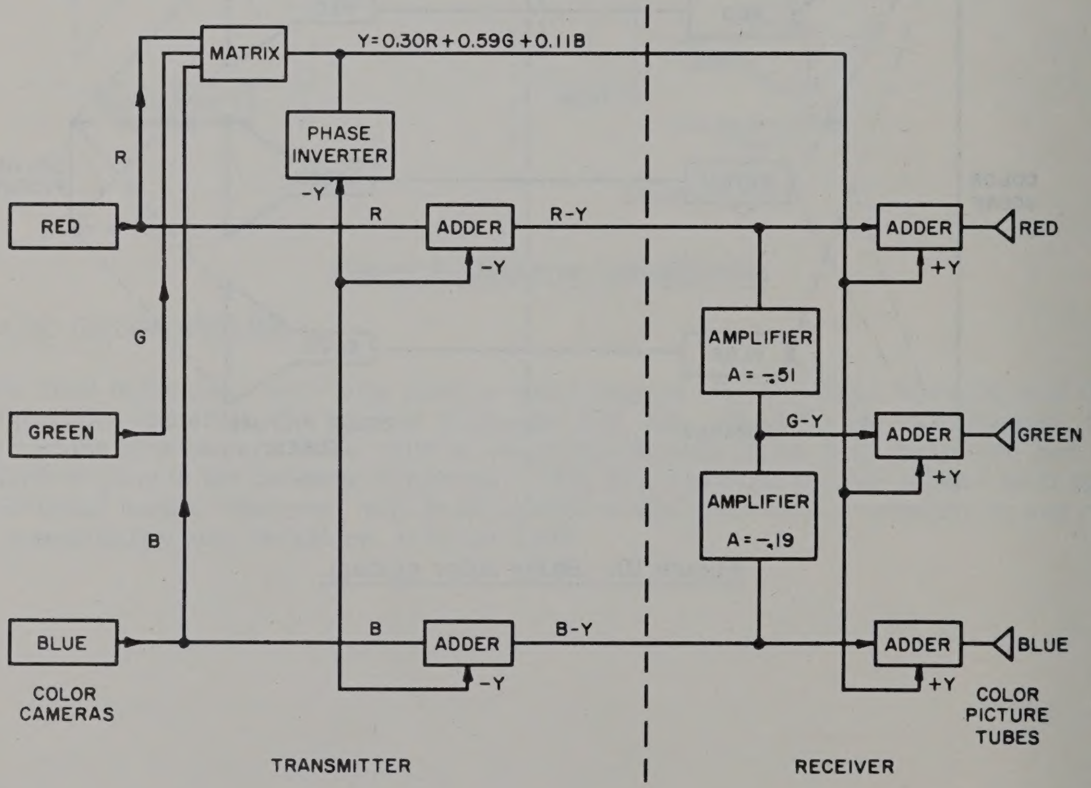

MATRIX
Y=0.30R+0.59G+0.11B
PHASE INVERTER
R
-Y
RED
R
ADDER
R-Y
-Y
G
GREEN
B
BLUE
B
ADDER
B-Y
-Y
COLOR CAMERAS
TRANSMITTER
ADDER
RED
+Y
AMPLIFIER
A = -.51
G-Y
ADDER
GREEN
+Y
AMPLIFIER
A = -.19
ADDER
BLUE
+Y
COLOR PICTURE TUBES
RECEIVER

Figure 11. Transmitter and receiver sections.

c. From this, it can be seen that four signals (Y, R-Y, G-Y, B-Y) should be transmitted to produce a color picture. However, only two color difference signals plus the Y signal are necessary. For example, the G-Y difference signal can be developed in the receiver since the R-Y and B-Y color difference signals contain all of the green color information. It remains only to adjust the percentages of the R-Y and B-Y color difference signals to produce the G-Y signal (fig. 11). Thus, -51 percent of the R-Y signal plus -19 percent of the B-Y signal produces the G-Y signal. The difference signals are then combined with the Y signal at the tricolor kinescope to produce the same signal found at the camera tube outputs. Although only two color difference signals are transmitted, all three color signals must be developed at the transmitter and receiver.

18. COLOR DIFFERENCE SIGNAL UTILIZATION

a. To understand the operation of the circuitry in figure 11, analyze the signal development, transmission, and reception of a fully saturated yellow scene. The red and green camera tubes operate with full output while the blue camera tube is inoperative. The outputs of the camera tubes combine in the matrix section. Since there is no output from the blue camera tube, the brightness ratio of blue (11 percent) is omitted from the Y-signal. The Y signal then becomes equal to 30 percent red plus 59 percent green.

b. The output of the matrix section is fed to the phase inverter in the transmitter. The output of the phase inverter is an inverted Y signal equal to -30 percent red -59 percent green. The inverted Y signal is added to the red and blue camera tube outputs in the transmitter adder stage to produce the R-Y and B-Y color difference signals:

$$R-Y = 100\%R - 30\%R - 59\%G = 70\%R - 59\%G$$
$$B-Y = 0\%B - 30\%R - 59\%G = -30\%R - 59\%G$$

The G-Y signal is then developed in the receiver section and is equal to -51 percent of the R-Y signal plus -19 percent of the B-Y signal:

$$G-Y = 41\%G - 30\%R - 11\%B$$

The color difference signals are then combined with the Y signal and applied to the tricolor kinescope, reproducing the signals as they appear at the outputs of the red and green camera tubes. The red and green signals thus developed combine on the face of the kinescope to produce yellow.

Section III. COLOR SIGNAL ANALYSIS

19. GENERAL

When a scene is televised, the output from the color camera tubes corresponds to the primary colors found in the color of the scene. The degree of saturation determines the percentage of the full output of the camera tubes. The brightness of the scene in relation to the total output of the camera tubes is determined by the matrix section. The output of the matrix section (the Y signal) is the sum of 30, 59, and 11 percent of the red, green, and blue camera tube outputs respectively. The transmitted color difference signals are developed by the addition of the inverted Y signal to the red and blue camera tube outputs. The inputs to the electron guns of the tricolor kinescope are the sum of the Y signal added to the transmitted R-Y and B-Y difference signals and the G-Y difference signal developed in the receiver.

20. ANALYSIS OF VIVID COLOR CAMERA OUTPUTS

a. The waveform analysis of a typical color scene is shown in figure 12. The waveforms represent various signals as indicated for one horizontal line scanning through red, green, blue, yellow, and white. The colors chosen are vivid ones, that is, they are fully saturated.

b. The red camera tube output shown indicates 100 percent when red is scanned. There will be no red camera tube output when green and blue are scanned. There will be 100 percent red camera tube output when yellow and white are scanned because both are partially composed of red. The green camera tube output will be zero when red and blue are scanned and 100 percent when green, yellow, and white are scanned. The blue camera tube output will be zero when red, green, and yellow are scanned and 100 percent when blue and white are scanned.

c. The camera tube outputs are fed into the matrix section of the transmitter where the Y signal is developed. When red is scanned, there is output only from the red camera tube. The Y signal uses 30 percent of this signal amplitude. When green is scanned, there is output only from the green camera tube. The Y signal uses 59 percent of this signal amplitude. When blue is scanned, there is output only from the blue camera tube. The Y signal uses 11 percent of this signal amplitude. When yellow is scanned, there is simultaneous output from the red and green camera tubes, but there is no output from the blue camera tube. The Y signal uses 30 percent of the red camera tube output and 59 percent of the green. When white is scanned, there is output from all three camera tubes. The amplitude of the Y signal is 100 percent and is composed of 30 percent of the red camera tube, 59 percent of the green, and 11 percent of the blue. The Y signal thus developed provides a monochrome receiver with the proper video signal and a color receiver with the brightness content of the televised scene.

21. ANALYSIS OF VIVID COLOR DIFFERENCE SIGNALS

a. In developing the color difference signals for fully saturated colors, certain ratios of the total camera tube outputs were established:

$$\begin{aligned} R-Y &= 70\%R - 59\%G - 11\%B \\ G-Y &= 41\%G - 30\%R - 11\%B \\ B-Y &= 89\%B - 30\%R - 59\%G \end{aligned}$$

The waveforms of these signals are shown in figure 12 when red, green, and blue colors of a televised scene are being scanned. However, the signals representing yellow and white have not been discussed. When a yellow scene is scanned, the waveforms of the color difference signals are represented by the sum of the red and green amplitudes which are 11 percent in the R-Y and G-Y signals, and -89 percent in the B-Y signal. When a white scene is scanned, the waveforms of the color difference signals are represented by the sum of the red, green, and blue signal amplitudes which is zero in each case.

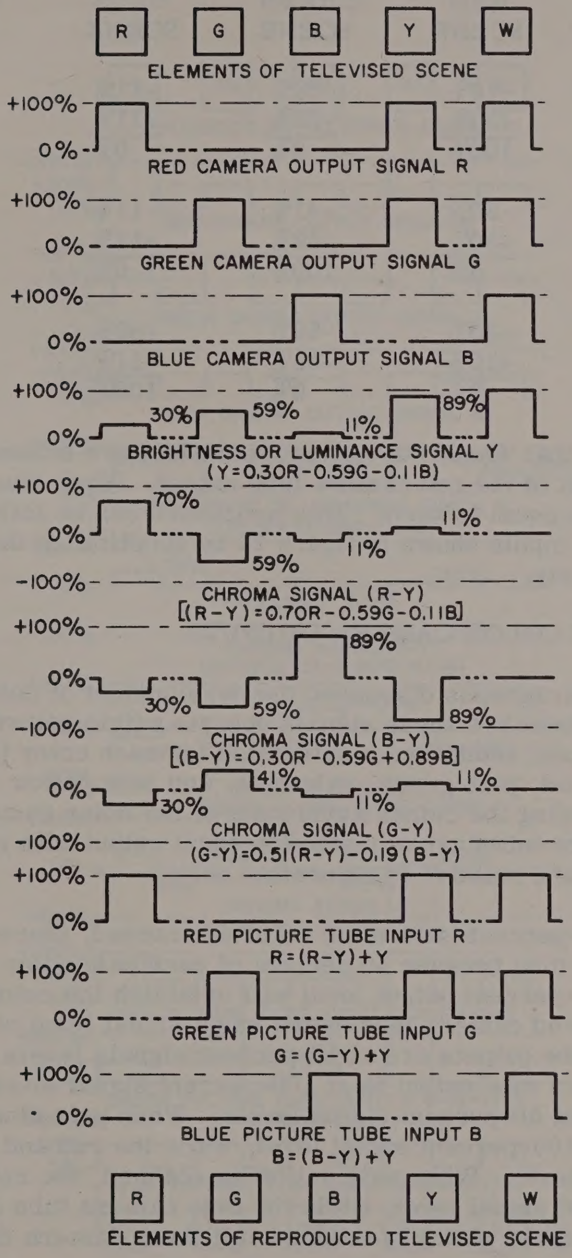

R
G
B
Y
W
ELEMENTS OF TELEVISED SCENE
+100%
0%
RED CAMERA OUTPUT SIGNAL R
+100%
0%
GREEN CAMERA OUTPUT SIGNAL G
+100%
0%
BLUE CAMERA OUTPUT SIGNAL B
+100%
30%
59%
11%
89%
0%
BRIGHTNESS OR LUMINANCE SIGNAL Y
(Y=0.30R-0.59G-0.11B)
+100%
70%
11%
0%
11%
59%
-100%
CHROMA SIGNAL (R-Y)
[(R-Y)=0.70R-0.59G-0.11B]
+100%
89%
0%
30%
59%
89%
-100%
CHROMA SIGNAL (B-Y)
[(B-Y)=0.30R-0.59G+0.89B]
41%
11%
0%
30%
11%
CHROMA SIGNAL (G-Y)
-100%
(G-Y)=0.51(R-Y)-0.19(B-Y)
+100%
0%
RED PICTURE TUBE INPUT R
R=(R-Y)+Y
+100%
0%
GREEN PICTURE TUBE INPUT G
G=(G-Y)+Y
+100%
0%
BLUE PICTURE TUBE INPUT B
B=(B-Y)+Y
R
G
B
Y
W
ELEMENTS OF REPRODUCED TELEVISED SCENE

Figure 12. Vivid color signal analysis.

b. The receiver reproduces the five colors being scanned by adding the Y signal to each color difference signal. The red, green, and blue kinescope inputs are equal to Y plus R-Y, Y plus G-Y, and Y plus B-Y, respectively, when red, green, blue, yellow, and white are scanned. This is represented in the table below.

TUBE	INPUT	RED SCENE	GREEN SCENE	BLUE SCENE	YELLOW SCENE	WHITE SCENE
R	R-Y	+70%	-59%	-11%	+11%	0%
	+Y	+30%	+59%	+11%	+89%	+100%
	R	100%	0%	0%	100%	100%
G	G-Y	-30%	+41%	-11%	+11%	0%
	+Y	+30%	+59%	+11%	+89%	+100%
	G	0%	100%	0%	100%	100%
B	B-Y	-30%	-59%	+89%	-89%	0%
	+Y	+30%	+59%	+11%	+89%	100%
	B	0%	0%	100%	0%	100%

From this it can be seen that when red, yellow, and white are scanned, the red kinescope input is equal to 100 percent of the red camera tube output. When blue and green are scanned, the red kinescope input is equal to zero. This procedure can be followed to determine the green and blue kinescope inputs shown in figure 12 by substituting the G-Y and B-Y color difference signals respectively.

22. ANALYSIS OF PALE COLOR CAMERA OUTPUTS

a. The preceding paragraphs discussed the development of color signals for fully saturated colors. To understand how these signals operate within saturation limits, analyze the same colors with 50-percent reduction in saturation for each color (fig. 13). Red, green, blue, and yellow become pale red, pale green, pale blue, and pale yellow respectively. White becomes gray. When analyzing the output waveforms of the color camera tubes, it must be remembered that the camera tubes are adjusted for equal output with respect to brightness. The output signal amplitudes are relative to saturation only.

b. When a pale (50-percent-saturated) color is scanned, there will be at least 50-percent output from each camera tube because 50 percent of each pale color is white. The camera tube outputs above the 50-percent output level will establish the color of the signal. When pale red is scanned, the red camera tube output has a signal level of 100 percent, while the blue and green camera tube outputs are at 50-percent signals levels. When pale green is scanned, the green camera tube output is at 100-percent signal level, while the red and blue camera tube outputs are at 50-percent signal levels. When pale blue is scanned, the blue camera tube output is at 100-percent signal level, while the red and green camera tube outputs are at 50-percent output level. When pale yellow is scanned, the red and green camera tube outputs are at 100-percent signal level, while the blue camera tube output is at 50-percent signal level. When gray (pale white) is scanned, all three camera tube outputs are at 50-percent signal level.

c. After matrixing, the Y signal that is developed is a product of 50 percent of the brightness ratios of the camera tube outputs plus the 50-percent signal level that comprises the white portion of the color. When red is scanned, there is 50-percent output from the green and blue camera tubes and 100-percent output from the red camera tube. The Y signal uses:

30% of the 100% red camera tube output (30%), plus
59% of the 50% green camera tube output (29.5%), plus

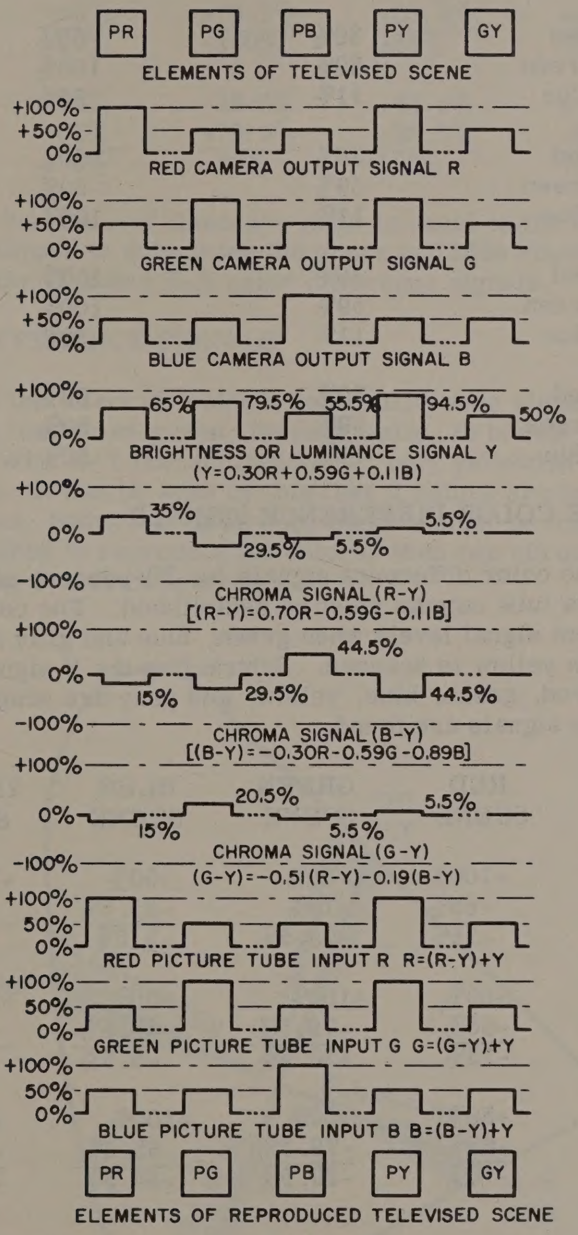

PR
PG
PB
PY
GY
ELEMENTS OF TELEVISED SCENE
+100%
+50%
0%
RED CAMERA OUTPUT SIGNAL R
+100%
+50%
0%
GREEN CAMERA OUTPUT SIGNAL G
+100%
+50%
0%
BLUE CAMERA OUTPUT SIGNAL B
+100%
65%
79.5%
55.5%
94.5%
50%
0%
BRIGHTNESS OR LUMINANCE SIGNAL Y
(Y=0.30R+0.59G+0.11B)
+100%
35%
5.5%
0%
29.5%
5.5%
-100%
CHROMA SIGNAL (R-Y)
[(R-Y)=0.70R-0.59G-0.11B]
+100%
44.5%
0%
15%
29.5%
44.5%
-100%
CHROMA SIGNAL (B-Y)
[(B-Y)=-0.30R-0.59G-0.89B]
+100%
20.5%
5.5%
0%
15%
5.5%
CHROMA SIGNAL (G-Y)
-100%
(G-Y)=-0.51(R-Y)-0.19(B-Y)
+100%
50%
0%
RED PICTURE TUBE INPUT R R=(R-Y)+Y
+100%
50%
0%
GREEN PICTURE TUBE INPUT G G=(G-Y)+Y
+100%
50%
0%
BLUE PICTURE TUBE INPUT B B=(B-Y)+Y
PR
PG
PB
PY
GY
ELEMENTS OF REPRODUCED TELEVISED SCENE

Figure 13. Pale color signal analysis.

11% of the 50% blue camera tube output (5.5%)

Thus, when red is scanned, the Y signal level is 65 percent. Following this procedure, the Y signal level can be determined for green, blue, yellow, and gray: Thus,

COLOR SCANNED	CAMERA TUBE	BRIGHTNESS RATIO	CAMERA TUBE OUTPUT	Y SIGNAL LEVEL
Pale Green	Red	30%	50%	79.5%
	Green	59%	100%	
	Blue	11%	50%	
Pale Blue	Red	30%	50%	55.5%
	Green	59%	50%	
	Blue	11%	100%	
Pale Yellow	Red	30%	100%	94.5%
	Green	59%	100%	
	Blue	11%	50%	
Gray	Red	30%	50%	50%
	Green	59%	50%	
	Blue	11%	50%	

23. ANALYSIS OF PALE COLOR DIFFERENCE SIGNALS

a. In developing the color difference signals for 50-percent-saturated colors, certain ratios of the total camera tube outputs must be established. The complete red camera tube output includes 50-percent signal levels when green, blue and gray are scanned and the 100-percent signal level when yellow is scanned. Subtracting the Y signal from this produces the signal levels when pale red, green, blue, yellow, and gray are scanned. Similarly, the G-Y and B-Y color difference signals are found.

CAMERA		RED	GREEN	BLUE	YELLOW	WHITE
TUBE	OUTPUT	SCENE	SCENE	SCENE	SCENE	SCENE
R	R	+100%	+50%	+50%	+100%	+50%
	-Y	-65%	-79%	-55.5%	-94.5%	-50%
	R-Y	+35%	-29.5%	-5.5%	+5.5%	0%
G	G	+50%	+100%	+50%	+100%	+50%
	-Y	-65%	-79.5%	-55.5%	-94.5%	-50%
	G-Y	-15%	+20.5%	-5.5%	+5.5%	0%
B	B	+50%	+50%	+100%	+50%	+50%
	-Y	-65%	-79.5%	-55.5%	-94.5%	-50%
	B-Y	-15%	-29.5%	+44.5%	-44.5%	0%

b. The receiver reproduces the five colors being scanned by adding the Y signal to each color difference signal.

TUBE	INPUT	RED SCENE	GREEN SCENE	BLUE SCENE	YELLOW SCENE	WHITE SCENE
R	R-Y	+35%	-29.5%	-5.5%	+5.5%	0%
	+Y	+65%	+79.5%	+55.5%	+94.5%	+50%
	R	+100%	+50%	+50%	+100%	+50%
G	G-Y	-15%	+20.5%	-5.5%	+5.5%	0%
	+Y	+65%	+79.5%	+55.5%	+94.5%	+50%
	G	+50%	+100%	+50%	+100%	+50%
B	B-Y	-15%	-29.5%	+44.5%	-44.5%	0%
	+Y	+65%	+79.5%	+55.5%	+94.5%	+50%
	B	+50%	+50%	+100%	+50%	+50%

From this it can be seen that the red kinescope input is equal to the red camera tube output. This procedure can be followed to determine the green and blue kinescope inputs shown in figure 13 by substituting the G-Y and B-Y color difference signals.

24. LOSS OF COLOR DIFFERENCE SIGNALS

Figure 14 illustrates the effect of losing a color difference signal. If only R-Y were transmitted, only colors along the bluish-green, through white, to bluish-red line would be reproduced on the kinescope. With B-Y transmitted alone, only yellowish-green, white, or reddish-blue would be reproduced. It can be seen by this that if colors are to be reproduced that do not fall on either of these lines, both color difference signals must be transmitted. Since the color television system is required to reproduce all colors, then two chrominance signals plus the Y signal are necessary to the system's operation.

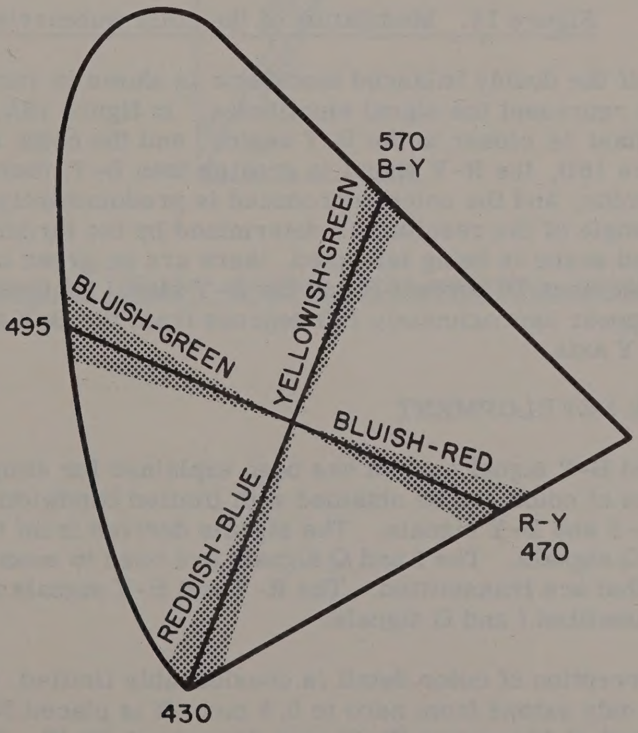


Figure 14. R-Y and B-Y chromaticity coordinates.

25. COMPOSITION OF THE COLOR SIGNAL

a. The color signal takes the form of a carrier with a frequency of approximately 3.58 mc. It is called a color subcarrier to distinguish it from the rf carrier. The subcarrier is sent to both sections of a doubly balanced modulator (fig. 15), one cw signal being 90 degrees out of phase with the other. The color difference signals are also applied to the modulator, the R-Y signal being sent to the modulator section receiving the subcarrier which leads the other by 90 degrees. The combined output forms one resultant subcarrier with the modulated intelligence contained in a series of sidebands above and below the 3.58-mc signal. The side band frequencies depend upon the scene being televised.

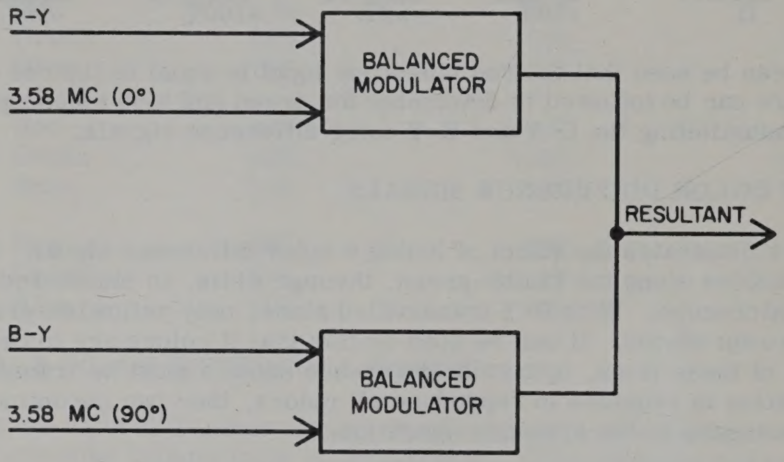


Figure 15. Modulation of the color subcarrier.

b. The output of the doubly balanced modulator is shown in vector form in figure 16. The length of the vectors represent the signal amplitudes. In figure 16A, B-Y is greater than R-Y; therefore, the resultant is closer to the B-Y vector, and the color reproduced is predominantly blue. In figure 16B, the R-Y signal is greater than B-Y; therefore, the resultant is closer to the R-Y vector, and the color reproduced is predominantly red. From this it can be seen that the phase angle of the resultant is determined by the largest color difference signal. For example, if a red scene is being televised, there are no green or blue voltages present and the R-Y signal becomes 70 percent R and the B-Y signal becomes -30 percent R. The resultant vector will appear approximately 113 degrees from the B-Y axis or approximately 23 degrees from the R-Y axis.

26. I AND Q SIGNAL DEVELOPMENT

a. The R-Y and B-Y signal system has been explained for simplicity. Actually, more faithful reproductions of color can be obtained with limited bandwidths by combining specific proportions of the R-Y and B-Y signals. The signals derived from the R-Y and B-Y signals are called the I and Q signals. The I and Q signals are used to modulate the color subcarrier and are the signals that are transmitted. The R-Y and B-Y signals are then derived in the receiver from the transmitted I and Q signals.

b. Because perception of color detail is considerably limited, the sideband frequencies of the Q signal need only extend from zero to 0.5 mc. It is placed 33 degrees from the B-Y signal and is composed of 48 percent (R-Y) plus 41 percent (B-Y). The I signal requires sideband frequencies from zero to 1.5 mc. It is placed 90 degrees from the Q signal, and is composed of 74 percent (R-Y) plus a minus 27 percent (B-Y). If the Y signal for fully saturated colors is substituted for Y in the preceding formulas, the I and Q signals can be expressed:

$$I = 60\%R - 28\%G - 32\%B$$
$$Q = 21\%R - 54\%G + 31\%B$$

c. The advantage of I and Q signals over the B-Y and R-Y signals is that the phase angle of the I signal places it in a coordinate designed to conform better with the color perception of the eye when objects of medium detail are televised.

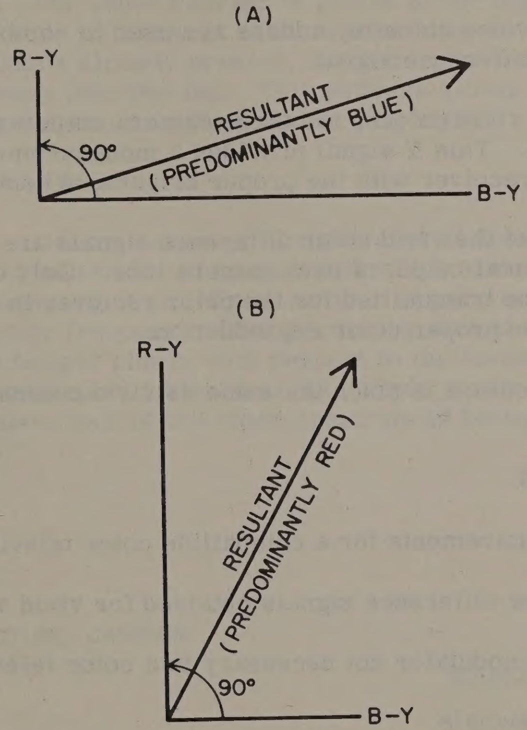

(A)
R–Y
RESULTANT
(PREDOMINANTLY BLUE)
90°
B–Y
(B)
R–Y
RESULTANT
(PREDOMINANTLY RED)
90°
B–Y

Figure 16. Vector analysis of the modulator output.

Section IV. SUMMARY AND REVIEW

27. SUMMARY

a. A color television system must provide high-definition black-and-white pictures which may be received by monochrome receivers without requiring modification of the receivers. This feature is known as compatibility.

b. Reverse compatibility is the reception of black-and-white pictures on a color receiver.

c. A method of producing chrominance signals is to develop color difference signals from the Y or brightness signal and the three camera tube outputs.

d. In the receiver video circuits, adders are used to combine the Y signal for a particular color with the color difference signal.

e. When televising vivid colors, the three camera outputs are fed into a matrix where the Y signal is developed. This Y signal provides a monochrome receiver with the proper video signal and a color receiver with the proper brightness content of the televised scene.

f. The amplitudes of the vivid color difference signals are obtained by subtracting the proper Y ratio from the total output of each camera tube. Only three signals, the Y, the I, and the Q signals, must be transmitted for the color receiver to derive the required R-Y and B-Y signals necessary for proper color reproduction.

g. Televising pale colors is much the same as vivid colors except that there is a reduction in saturation.

28. REVIEW QUESTIONS

a. What are the requirements for a compatible color television system?

b. How are the color difference signals obtained for vivid and pale colors?

c. Why is a G-Y demodulator not necessary in a color television receiver?

d. Explain I and Q signals.

CHAPTER 3

COLOR TELEVISION TRANSMISSION

Section I. INTRODUCTION

29. TRANSMISSION WITHIN THE 6-MC TELEVISION CHANNEL

The monochrome signal displacement within the standard television channel is illustrated in figure 17. The video signal occupies approximately 5.35 mc with a small guardband at the high- and low-frequency end. The sound carrier is placed at the high-frequency end of the signal. It might seem impossible to transmit chrominance information within this space without seriously affecting the signals already present, but chrominance signals are included by using a process called frequency interleaving. This process allows transmission of the composite color signal in the same channel as the monochrome signal.

30. FREQUENCY INTERLEAVING

a. Energy produced by scanning an image concentrates at specific intervals in the frequency spectrum. These intervals occur at frequencies which are multiples of the scanning rate. Any video signal is composed of an infinite number of pure sine waves, each of which has a fundamental or a harmonic frequency of the recurring rate of the waveform. Since the picture composition usually changes slowly with respect to the frame frequency, the signal will consist primarily of frequencies clustered around whole number multiples of the frame and line frequencies. Only about half of the video spectrum is being used.

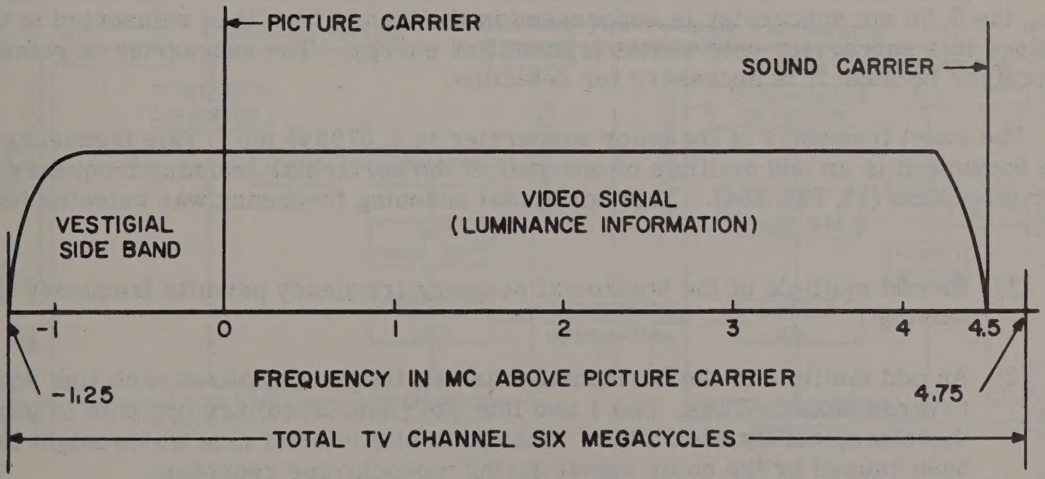

PICTURE CARRIER
SOUND CARRIER
VIDEO SIGNAL
(LUMINANCE INFORMATION)
VESTIGIAL
SIDE BAND
-1
0
1
2
3
4
4.5
-1.25
FREQUENCY IN MC ABOVE PICTURE CARRIER
4.75
TOTAL TV CHANNEL SIX MEGACYCLES

Figure 17. Frequency allocation of a television channel

b. Both the color (I and Q) and the luminance (Y) signals have the same scanning rates, so the concentrations of energy produced by both are spaced at the same intervals. Therefore, the band of concentrated energy of the color signal could be spaced between the bands of the monochrome signal. In figure 18, the spaces occur at odd multiples of one-half the line frequency. The color and monochrome signals will be interleaved if the color subcarrier frequency is equal to an odd multiple of one-half the line frequency.

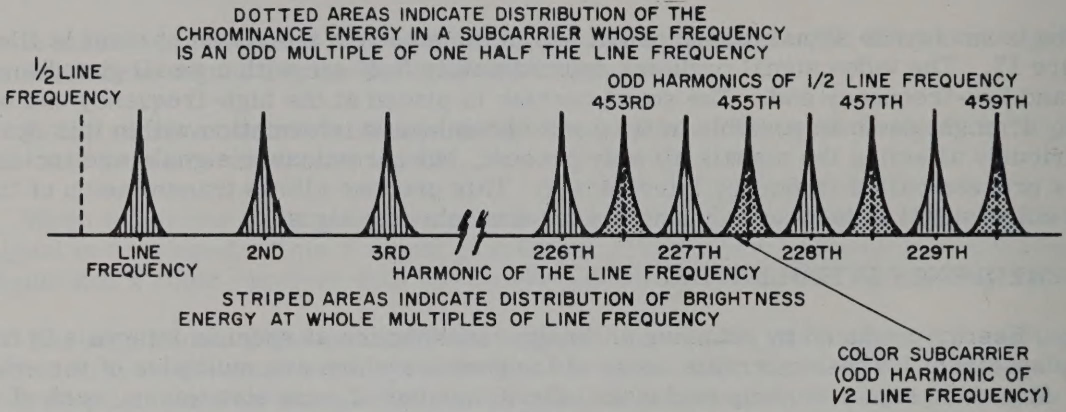

DOTTED AREAS INDICATE DISTRIBUTION OF THE CHROMINANCE ENERGY IN A SUBCARRIER WHOSE FREQUENCY IS AN ODD MULTIPLE OF ONE HALF THE LINE FREQUENCY
½ LINE FREQUENCY
ODD HARMONICS OF 1/2 LINE FREQUENCY
453RD
455TH
457TH
459TH
LINE FREQUENCY
2ND
3RD
226TH
227TH
228TH
229TH
HARMONIC OF THE LINE FREQUENCY
STRIPED AREAS INDICATE DISTRIBUTION OF BRIGHTNESS ENERGY AT WHOLE MULTIPLES OF LINE FREQUENCY
COLOR SUBCARRIER (ODD HARMONIC OF 1/2 LINE FREQUENCY)

Figure 18. Interleaving luminance and chrominance signals.

31. CHROMINANCE SUBCARRIER SIGNAL

a. The color subcarrier is placed high on the video band, approximately 3.58 mc from the picture carrier. Placing the color subcarrier at 3.58 mc permits the use of the maximum bandwidth of chrominance signals without causing interference with the brightness signal. In practice, the 3.58 mc subcarrier is suppressed in the transmitter then reinserted in the receiver since this subcarrier only wastes transmitter energy. The subcarrier is reinserted in the receiver because it is necessary for detection.

b. The exact frequency of the color subcarrier is 3.579545 mc. This frequency was selected because it is an odd multiple of one-half of the horizontal scanning frequency used for color television (15,734.264). This horizontal scanning frequency was selected for three reasons:

(1) An odd multiple of the horizontal scanning frequency permits frequency interleaving.

(2) An odd multiple of the horizontal scanning frequency causes each line scanned to reverse phase. Thus, line 1 and line 526 (interlaced) are opposite in phase and, therefore, nullify each other. This prohibits interference which might have been caused by the color signal during monochrome reception.

(3) The 920-kc beat frequency between the color subcarrier and the 4.5 mc intercarrier sound signal in the receiver is less objectionable if it is equal to an odd multiple of one-half the horizontal scanning frequency.

c. Changing the horizontal scanning frequency means that the vertical scanning rate also must be changed. The vertical scanning rate for a color telecast has been lowered from 60 cps to 59.94 cps.

32. SIGNAL TRANSMISSION IN QUADRATURE

a. It has been shown in the preceding chapter that two chrominance signals are necessary to reproduce all colors. Both of these signals must have bandwidth, and this bandwidth increases as the color definition increases. Since there is a limited amount of space in the Y video sideband to place these signals, a special method is used which combines the chrominance signals in quadrature. The two chrominance signals are displaced in phase by 90 degrees and amplitude modulated at the subcarrier frequency. The amplitude-modulated signals are combined to form a single modulation envelope that is the resultant of the two differently phased signals. When detected by a phase-sensitive device in the receiver, the original signals are separated from the resultant signal.

b. Figure 19 is a block diagram of a system in which chrominance signals are transmitted in quadrature. The two color-difference signals are amplitude modulated on a common 3.58-mc carrier; however, the R-Y signal is shifted 90 degrees in phase from the B-Y signal. These two signals are combined at the output of their respective modulators and added to the Y sidebands in the adder. At the receiver, chrominance information is separated from the Y signal and applied to two synchronous detectors which are phase-sensitive detectors. The outputs of the synchronous detectors are the original R-Y and B-Y signals developed at the transmitter.

c. The 3.58-mc chrominance subcarrier is suppressed in the transmitter and must be reinserted at the receiver. A 3.58-mc oscillator in the receiver generates a signal which is divided into two components displaced 90 degrees in phase. These are combined with the chrominance signal and detection takes place in the synchronous detectors. The 3.58-mc oscillator in the receiver must be synchronized with the 3.58-mc oscillator at the transmitter. To maintain synchronization of the oscillators, a color-synchronizing signal is transmitted.

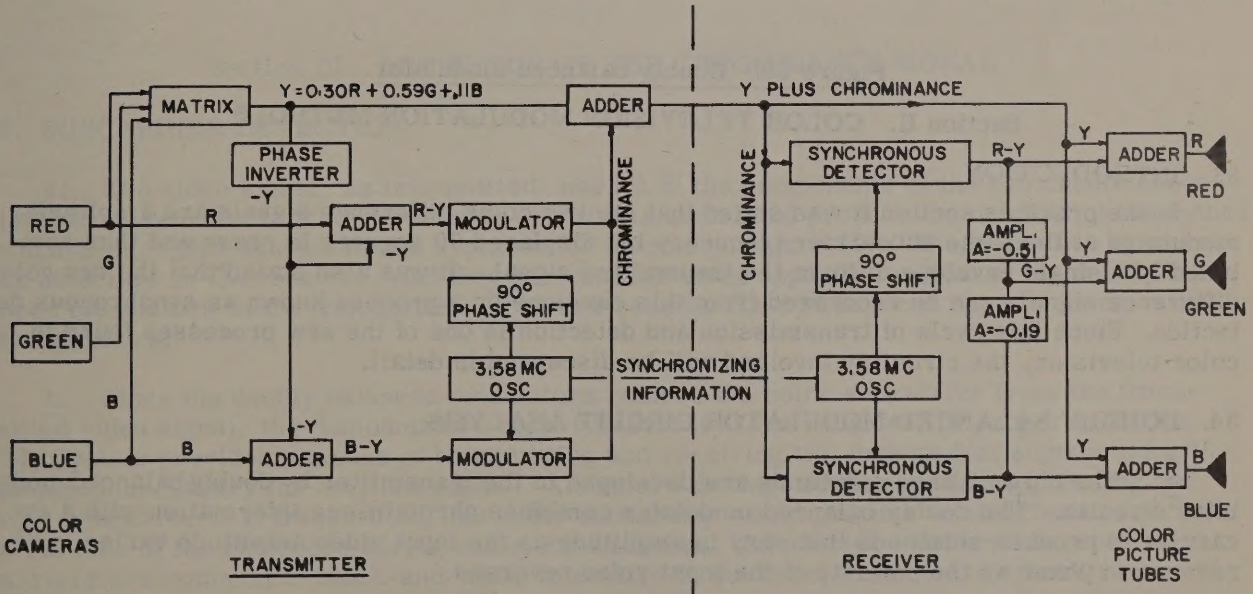

Y=0.30R + 0.59G+.11B
MATRIX
ADDER
Y PLUS CHROMINANCE
PHASE INVERTER
-Y
RED
R
ADDER
R-Y
MODULATOR
-Y
G
90° PHASE SHIFT
GREEN
3.58 MC OSC
SYNCHRONIZING INFORMATION
B
-Y
BLUE
B
ADDER
B-Y
MODULATOR
COLOR CAMERAS
TRANSMITTER
CHROMINANCE
CHROMINANCE
SYNCHRONOUS DETECTOR
R-Y
Y
ADDER
R
RED
AMPL. A=-0.51
Y
G-Y
ADDER
G
GREEN
90° PHASE SHIFT
AMPL. A=-0.19
3.58 MC OSC
SYNCHRONOUS DETECTOR
B-Y
Y
ADDER
B
BLUE
COLOR PICTURE TUBES
RECEIVER

Figure 19. Block diagram of R-Y, B-Y transmitter and receiver.

d. When the chrominance signal at the grid of the modulator tubes shown in figure 20 is positive it produces a larger amplitude carrier output than when it is negative. This condition also applies to the second demodulator tube except that the chrominance signal starts in a negative direction. Thus, the modulated output starts with a signal that is low in amplitude. Since the plates are tied together, the outputs of the modulator tubes combine to form the resultant shown. Note that the video signal does not appear in the output. The amplitude of the resultant is equal to the difference in the amplitude of the two signals, and the phase corresponds to the signal having the greatest amplitude.

e. Increasing the signal applied to the phase splitter will increase the amplitude of the modulated signal. Reversing the polarity of the signal applied to the phase splitter will reverse the phase of the modulated signal. If either the cw signal or the modulating signal is absent, there will be no output because the signals applied will cancel themselves.

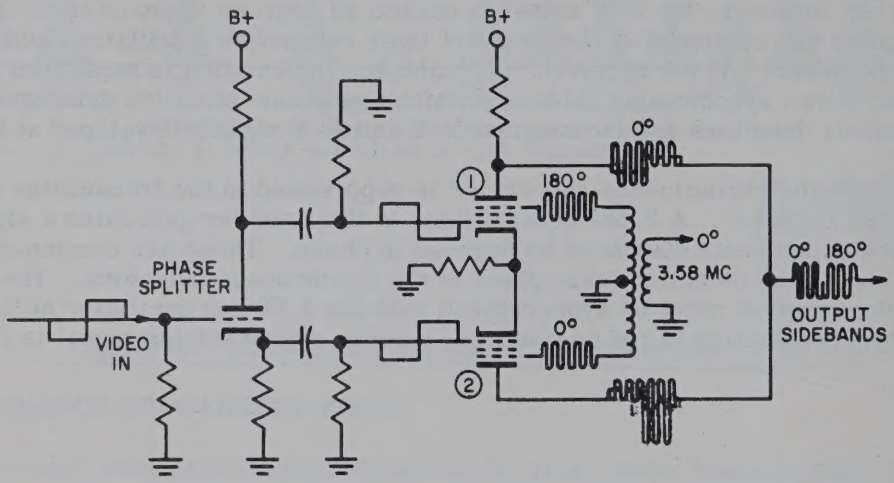


Figure 20. Doubly balanced modulator.

Section II. COLOR TELEVISION MODULATION METHODS

33. INTRODUCTION

In the previous section it was stated that the two color difference signals are amplitude modulated at the same subcarrier frequency but displaced 90 degrees in phase and then combined in a single envelope to form the transmitted signal. It was also stated that the two color difference signals can be recovered from this envelope by a process known as synchronous detection. Since this cycle of transmission and detection is one of the new processes found in color television, the circuitry involved will be discussed in detail.

34. DOUBLY BALANCED MODULATOR CIRCUIT ANALYSIS

a. The chrominance sidebands are developed in the transmitter by doubly balanced modulator circuits. The doubly balanced modulator combines chrominance information with a cw carrier to produce sidebands that vary in amplitude as the input video amplitude varies, and reverse in phase as the polarity of the input video reverses.

b. In the simplified diagram of a doubly balanced modulator shown in figure 20, the input stage is a phase splitter which supplies signal outputs of equal amplitude to the plate and cathode. The signal at the plate is 180 degrees out of phase with the input signal, but the signal at the cathode is in phase with the input signal. The outputs of the phase splitter are applied to the control grids of two modulator tubes. The modulator tubes, therefore, have signals on the control grids that are equal in amplitude but opposite in phase.

c. The suppressor grids of the modulators are also signal grids, being fed by the opposite ends of a transformer which is driven by a 3.58-mc cw signal. Since the extremes of any transformer winding provide signals with a 180-degree phase difference, the suppressor grids of the modulators are also fed by signals that are equal in amplitude but 180 degrees out of phase.

35. DEVELOPMENT OF MODULATOR PHASE DIFFERENCE

a. It was mentioned that there are two doubly balanced modulators, each modulated by a chrominance signal. The two modulators are adjusted so that there is a 90-degree phase difference between them. The output of one modulator is either 0 or 180 degrees, depending upon the polarity of the video input; the other modulator produces an output that is either 90 or 270 degrees. When one modulator output is 0 degree and the other is 90 degrees, the combined resultant signal will fall somewhere between 0 and 90 degrees, depending upon the amplitude relationships of the two original signals. For example, if the modulator output amplitude at zero degree is high compared to the output amplitude of the other, the phase of the combined signal will fall somewhere close to 0 degree.

b. From the following chart it can be seen that when the polarity of the color difference video signals changes, the phase of the combined chrominance sidebands can vary from 0 to 360 degrees. The amplitude of the resultant sideband is a direct function of the video input amplitudes.

When B-Y phase is:	and	R-Y phase is:	The phase of the resultant will fall between:
0°		90°	0° and 90°
180°		90°	90° and 180°
180°		270°	180° and 270°
0°		270°	270° and 360°

Section III. DETECTION OF THE CHROMINANCE SIGNAL

36. SUBCARRIER DETECTION

a. The video signal, as transmitted, has all of the components of the two chrominance signals. It remains for the receiver to detect this signal and produce the original chrominance information. This is done by the synchronous detectors (figure 19). There are two synchronous detectors in the receiver, and they perform the exact opposite function of the doubly balanced modulators in the transmitter. For this reason, the synchronous detectors are called demodulators.

b. Since the doubly balanced modulators remove the color subcarrier from the transmitted video signal, the demodulators must reinsert it at the receiver for proper detection. This system provides a means of transmitting and receiving two independent signals using the bandwidth necessary for only one signal. There are distinct advantages in suppressing the color subcarrier. If transmitted, the color subcarrier would produce an interference pattern on the face of the kinescope during color transmission. Interference patterns between signal carriers are common to black-and-white television in the form of the 4.5-mc beat frequency produced between the sound and picture carriers. Since this beat frequency is outside the video response of the receiver, it can be easily eliminated. However, in the case of the color subcarrier, a beat will occur between it and the sound carrier at 920 kc (4.5 mc-3 58 mc). Since this falls well within the video response of the receiver, it is not eliminated. The carrier interference problem is minimized, however, by not transmitting the color subcarrier.

37. COLOR BURST SYNCHRONIZATION

a. Detection of the color subcarrier sidebands would not be possible if exact phase relationships were not maintained between the 3.58-mc subcarrier oscillators in the transmitter and receiver. In order to maintain these two oscillators in phase, a short burst of the transmitter oscillator voltage is transmitted at the beginning of each horizontal scanning line. This burst is frequent enough and of sufficient duration to ensure that the receiver oscillator is in exact phase relationship with the transmitter oscillator.

b. The burst consists of approximately eight cycles of the 3.58-mc signal and is placed on the back porch of the horizontal blanking pedestal next to the horizontal synchronizing pulse, as shown in figure 21.

c. The color burst does not interfere with horizontal synchronization because it is lower in amplitude than the synchronizing pulse. The burst functions in a manner similar to scanning synchronization. Applied to the proper circuits, it produces a correction voltage in the form of bias that maintains the receiver 3.58-mc oscillator at the proper phase.

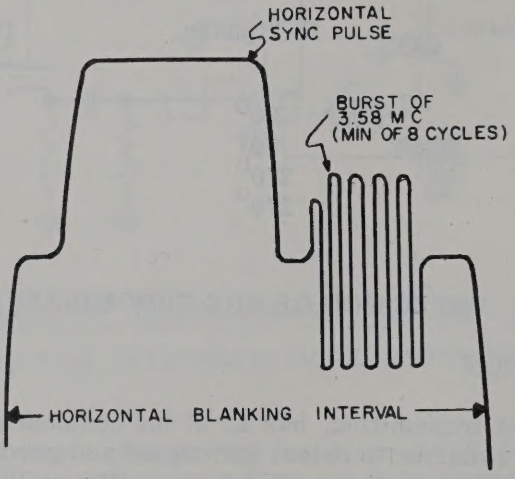

HORIZONTAL SYNC PULSE
BURST OF 3.58 MC (MIN OF 8 CYCLES)
HORIZONTAL BLANKING INTERVAL

Figure 21. The color synchronizing signal.

Section IV. BANDWIDTH LIMITATIONS

38. COLOR DEFINITION

a. The highest usable video brightness signal frequency is 4.1 mc, with the chrominance subcarrier at 3.58 mc. Transmitting symmetrical or double sidebands of chrominance information would limit color definition to 0.5 mc, and color would be absent in all fine detail in the picture. It is possible, however, to transmit the chrominance sideband vestigially, that is, with one sideband partially suppressed, the same as the black-and-white signal. This would permit extension of the color definition to 1.5 mc. One of the chrominance signals would extend from 0 to 1.5 mc, and the other color difference signal would be limited to 0 to 0.5 mc. It will be noted, from figure 14, that if R-Y were the extended sideband, only bluish red or a bluish green would be reproduced in fine detail. If B-Y were the extended sideband, only reddish-green or yellowish-green colors would be reproduced in fine detail.

b. A complete range of fine color detail can be represented accurately to the eye by orange or cyan. To use R-Y and B-Y signals, it would be necessary to transmit extended sidebands of both color difference signals, since both are necessary to reproduce either orange or cyan. However, it is not possible to extend both signals to 1.5 mc; therefore, it can be seen that color definitions using the color difference signals must be limited to 0.5 mc of sideband extension, and therefore cannot represent full color fidelity of the televised scene.

39. WIDE BANDWIDTH CONSIDERATIONS

a. Since color areas, beyond a certain fineness of detail, can be accurately represented to the eye by either orange or cyan, the axes of the chrominance subcarrier signals were shifted in phase from the reference subcarrier so that one of the axes would represent orange and cyan, with the other axis at right angles to it. The orange-cyan axis could then be extended to 1.5 mc, and since the fine detail conveyed by this extended bandwidth need be only orange or cyan to represent color accurately to the eye, full-color fidelity would be possible in picture detail up to 1.5 mc of picture definition. The eye is not capable of detecting extremely fine color detail, and only a brightness variable is necessary to represent an object as having color.

b. By readjusting the phase of the chrominance signals and transmitting one signal vestigially with extended bandwidth, all colors are faithfully reproduced in picture detail from 0 to 0.5 mc. Beyond this point one of the chrominance signals drops out. With the orange-cyan signal still present to 1.5 mc, the eye still sees effectively all color though only orange and cyan are transmitted. The eye is not capable of distinguishing color in picture detail represented by video frequencies beyond 1.5 mc. With no chrominance signals transmitted beyond this point, the brightness signal accurately conveys the illusion of color in video detail from 1.5 to 4.1 mc.

40. HIGH-DEFINITION COLOR TRANSMISSION

a. The readjustment of chrominance signal phases is called high-definition color transmission and is the system of color transmission used today. Since the chrominance axes in this system are not the same as R-Y and B-Y they have been given new titles. One is called the "I" signal since it is nearest in phase to the "first" or the reference subcarrier, and the other is called the "Q" signal since it is in quadrature with the "I" signal.

b. Figure 22 is a vector diagram of the I and Q color coordinates. The colors represented by the I and Q signals are plotted on the chromaticity diagram in figure 23. The I axis is the orange-cyan line and the Q axis is the green-magenta line. Comparison with figure 14 shows the relative position of the R-Y and B-Y chromaticity coordinates.

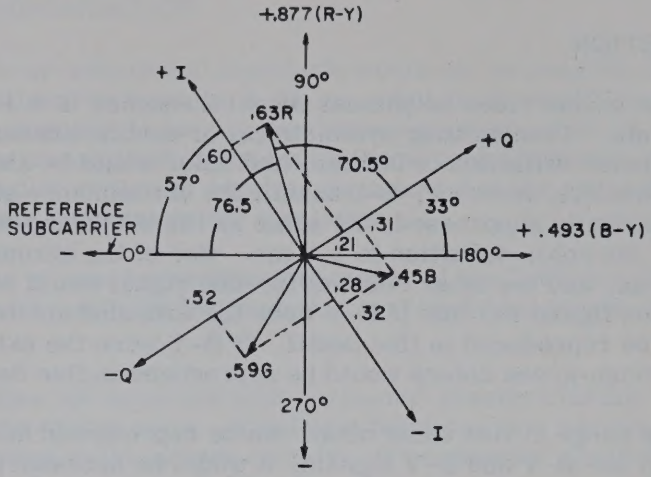

+.877(R-Y)
+ I
90°
.63R
+Q
.60
70.5°
57°
REFERENCE SUBCARRIER
76.5
33°
.31
+ .493(B-Y)
.21
− 0°
180°
.45B
.28
.52
.32
−Q
.59G
270°
− I

Figure 22. I and Q vector coordinates.

c. Making this shift at the transmitter requires adjustment of the phases of the doubly balanced modulators. It will be remembered that one signal was produced with the doubly balanced modulator in phase (or 180 degrees out of phase) with the reference subcarrier. The other doubly balanced modulator was in quadrature (90 or 270 degrees) from the reference subcarrier. The I and Q signals are produced with their phase coordinates 90 degrees from each other, but the +I signal is 57 degrees from the reference subcarrier, with -I at 237 degrees (180 degrees from +I). The +Q signal is displaced 57 degrees +90 degrees, or 147 degrees, with the -Q signal 180 degrees from it, or 327 degrees from the reference subcarrier.

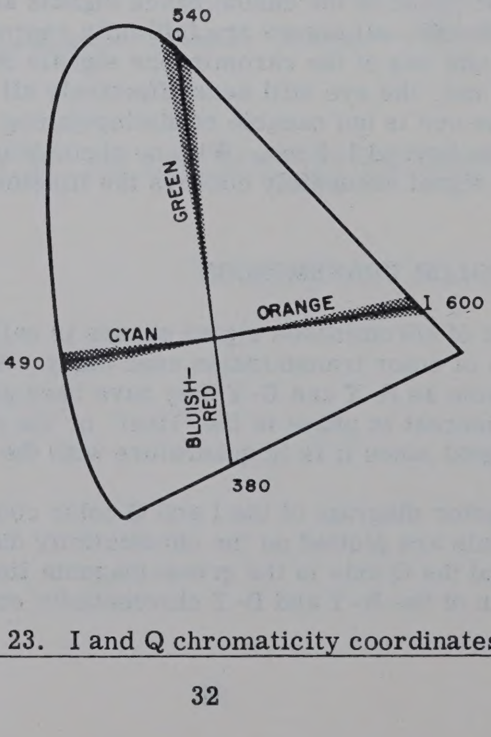

540
Q
GREEN
ORANGE
I 600
CYAN
490
BLUISH-RED
380

Figure 23. I and Q chromaticity coordinates.

41. I AND Q SIGNAL DEVELOPMENT

a. Figure 24 is a block diagram of a color television transmitter capable of producing a color signal with I and Q chromaticity coordinates. In the matrix section, the Y signal maintains the ratio 30:59:11 for red, green, and blue camera with black-and-white standards. The red and green camera signals enter the I and Q matrix through phase inverters since the red and green signals must be negative to form I and Q respectively. The filter section establishes a bandpass for each of the video signals, 0-4.1 mc for Y, 0-1.5 mc for I, and 0-0.5 mc for Q. These signals are of different bandwidths; the widest bandwidth has the least time delay. Since the signals must have a specific placement with regard to each other, the I and Y signals are sent through delay networks so that all three signals will have the proper time placement when applied to the mixer section. The I and Q video signals are applied to the modulator section where they produce the chrominance signals. Notice that the reference subcarrier frequency is phase-shifted 57 degrees before being applied in quadrature to the doubly balanced modulators. The three video signals plus burst and synchronization are combined in the mixer section to produce the composite video signals and sent on to the receiver.

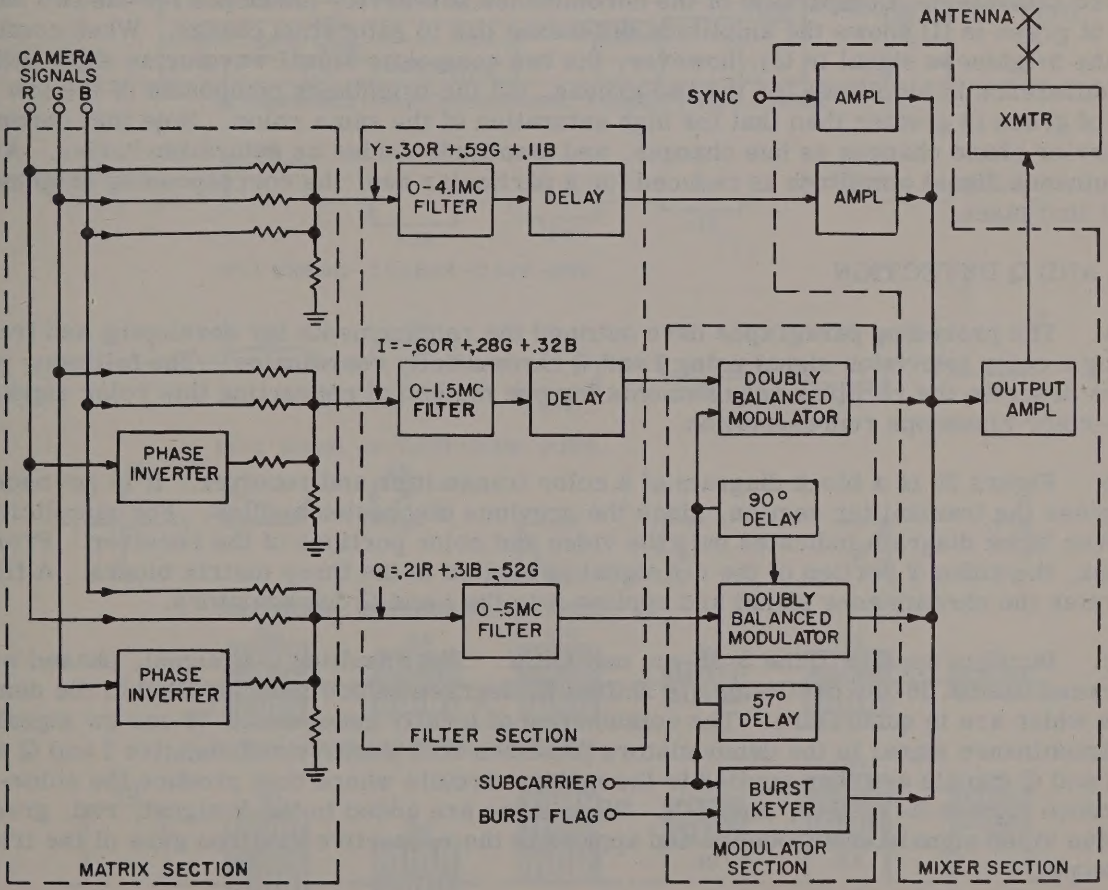

ANTENNA
CAMERA SIGNALS
R G B
SYNC
AMPL
XMTR
Y=.30R +.59G +.11B
0-4.1MC FILTER
DELAY
AMPL
I=-.60R +.28G +.32B
0-1.5MC FILTER
DELAY
DOUBLY BALANCED MODULATOR
OUTPUT AMPL
PHASE INVERTER
90° DELAY
Q=.21R +.31B -.52G
0-.5MC FILTER
DOUBLY BALANCED MODULATOR
PHASE INVERTER
57° DELAY
FILTER SECTION
SUBCARRIER
BURST FLAG
BURST KEYER
MATRIX SECTION
MODULATOR SECTION
MIXER SECTION

Figure 24. Color television transmitter.

b. Figure 25 illustrates the signal development for the colors indicated. The high saturation of red, blue, green, and yellow is considered to be 100 percent. The low saturation of green and yellow is considered to be 50 percent. The shaded areas of the three camera-tube output signals (B, C, and D) represent the white component of the 50-percent-saturated green and yellow.

c. By applying the formula Y = 30%R + 59%G + 11%B to all three camera-tube output signals for any one color, the Y-signal waveform, shown in (E), will be developed. When applied to a black-and-white receiver, this video waveform will represent the brightness characteristic of the colors illustrated.

d. The I signal, shown in (F), is developed by applying the formula I = 60%R - 32%B - 28%G to the three camera signal output waveforms for any color shown. Similarly, the Q signal, shown in (G), is developed by applying the formula Q = 21%R + 31%B - 52%G. The I and Q signals, combined in quadrature, form the chrominance subcarrier signal; the signal phases and amplitudes for the colors shown are indicated in (H). If the I axis is rotated to correspond with figure 22, the amplitudes and phase angles will also correspond. The high saturation of green, for example, has a chrominance signal amplitude of .59 at a certain phase. The amplitude and phase are determined by the amplitudes of -I and -Q produced for green.

e. Note that the pale green chrominance subcarrier vector has not changed in phase from the highly saturated green, but is merely reduced in amplitude in order to convey the effect of reduced saturation. Comparison of the chrominance subcarrier envelopes for the two saturations of green in (I) shows the amplitude difference due to saturation change. When combined with the brightness signal in (J), however, the two composite signal waveforms show little total difference in amplitude for the two greens, but the brightness component of the low saturation of green is greater than that for high saturation of the same color. Note that chrominance subcarrier phase changes as hue changes, and amplitude varies as saturation varies. As chrominance signal amplitude is reduced for a particular hue, the corresponding brightness signal increases.

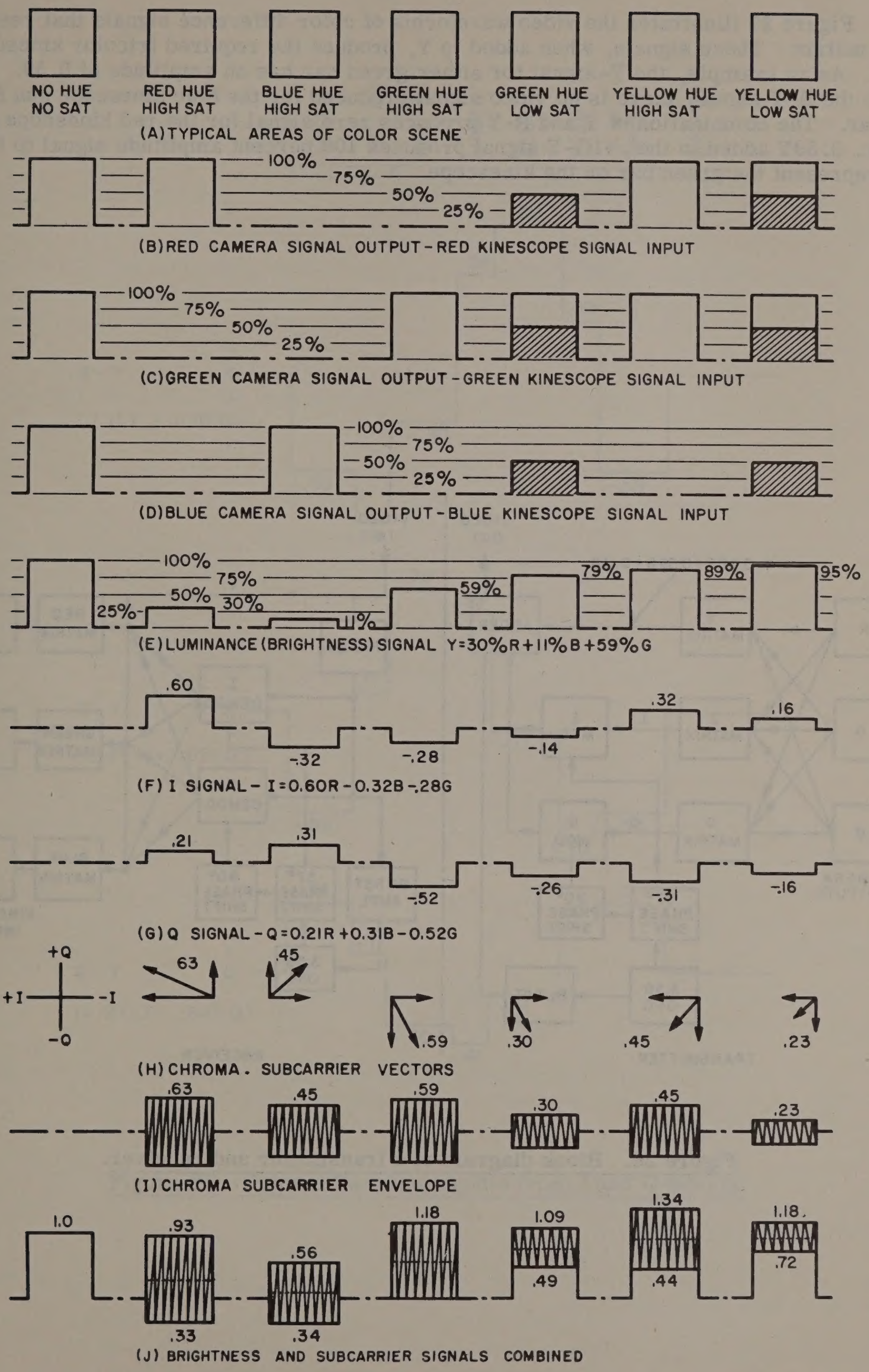
42. I AND Q DETECTION

a. The preceding paragraphs have outlined the requirements for developing and transmitting a color television signal using I and Q chromaticity coordinates. The following paragraphs describe the receiver requirements for one method of converting this color signal into a full-color kinescope representation.

b. Figure 26 is a block diagram of a color transmitter and receiver. It is not necessary to discuss the transmitter section, since the previous discussion applies. For simplicity, the receiver block diagram indicates only the video and color portions of the receiver. From the antenna, the video Y portion of the r-f signal is applied to the three matrix blocks. A filter separates the chrominance signal and applies it to the I and Q demodulators.

c. Burst is applied to the 3.58-mc oscillator. The resulting c-w signal, phased with the transmitter 3.58-mc oscillator, is shifted 57 degrees before being applied to the demodulators which are in quadrature. The combination of locally generated 3.58-mc cw signals and the chrominance signal in the demodulators produces both positive and negative I and Q signals. The I and Q signals are then applied to the matrix circuits where they produce the color-difference signals R-Y, G-Y, and B-Y. When these are added to the Y signal, red, green, and blue video signals are produced and applied to the respective electron guns of the tricolor kinescope.

d. Note that the I and Q signals produce color-difference signals which, when added to Y, duplicate the output signals of the three camera tubes. Figure 26 also shows that signal development in the receiver is the exact reverse of that in the transmitter.


NO HUE NO SAT
RED HUE HIGH SAT
BLUE HUE HIGH SAT
GREEN HUE HIGH SAT
GREEN HUE LOW SAT
YELLOW HUE HIGH SAT
YELLOW HUE LOW SAT
100%
75%
50%
25%
25%-
30%
11%
59%
79%
89%
95%
.60
-.32
-.28
-.14
.32
.16
.21
.31
-.52
-.26
-.31
-.16
+Q
+I
-I
-Q
63
.45
.59
.30
.45
.23
.63
.45
.59
.30
.45
.23
1.0
.93
.33
.56
.34
1.18
1.09
.49
1.34
.44
1.18
.72

(A) TYPICAL AREAS OF COLOR SCENE

(B) RED CAMERA SIGNAL OUTPUT - RED KINESCOPE SIGNAL INPUT

(C) GREEN CAMERA SIGNAL OUTPUT - GREEN KINESCOPE SIGNAL INPUT

(D) BLUE CAMERA SIGNAL OUTPUT - BLUE KINESCOPE SIGNAL INPUT

(E) LUMINANCE (BRIGHTNESS) SIGNAL Y=30%R+11%B+59%G

(F) I SIGNAL - I=0.60R-0.32B-.28G

(G) Q SIGNAL - Q=0.21R+0.31B-0.52G

(H) CHROMA. SUBCARRIER VECTORS

(I) CHROMA SUBCARRIER ENVELOPE

(J) BRIGHTNESS AND SUBCARRIER SIGNALS COMBINED

Figure 25. Evolution of the color signal.

e. Figure 27 illustrates the video waveforms of color difference signals that result from I and Q matrix. These signals, when added to Y, produce the required tricolor kinescope grid signals. As an example, the Y-signal for either green bar has an amplitude of 0.59. When added to the B-Y signal, there is no video signal produced for the blue kinescope gun for the green bar. The combination of Y and R-Y produces zero signal for the red kinescope gun; however, 0.59Y added to the .41G-Y signal produces 100 percent amplitude signal to the green gun to represent the green bar on the kinescope.

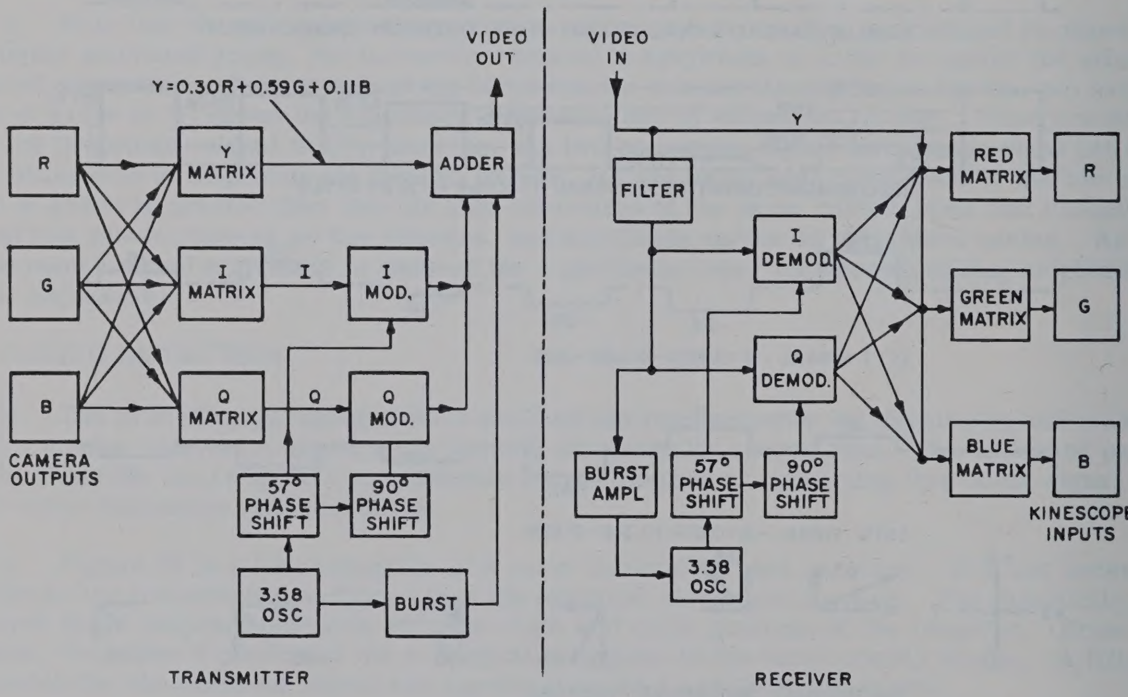

VIDEO OUT
VIDEO IN
Y=0.30R+0.59G+0.11B
R
G
B
CAMERA OUTPUTS
Y MATRIX
I MATRIX
Q MATRIX
I
Q
I MOD.
Q MOD.
ADDER
57° PHASE SHIFT
90° PHASE SHIFT
3.58 OSC
BURST
TRANSMITTER
Y
FILTER
I DEMOD.
Q DEMOD.
BURST AMPL
57° PHASE SHIFT
90° PHASE SHIFT
3.58 OSC
RED MATRIX
GREEN MATRIX
BLUE MATRIX
R
G
B
KINESCOPE INPUTS
RECEIVER

Figure 26. Block diagram of a transmitter and receiver.

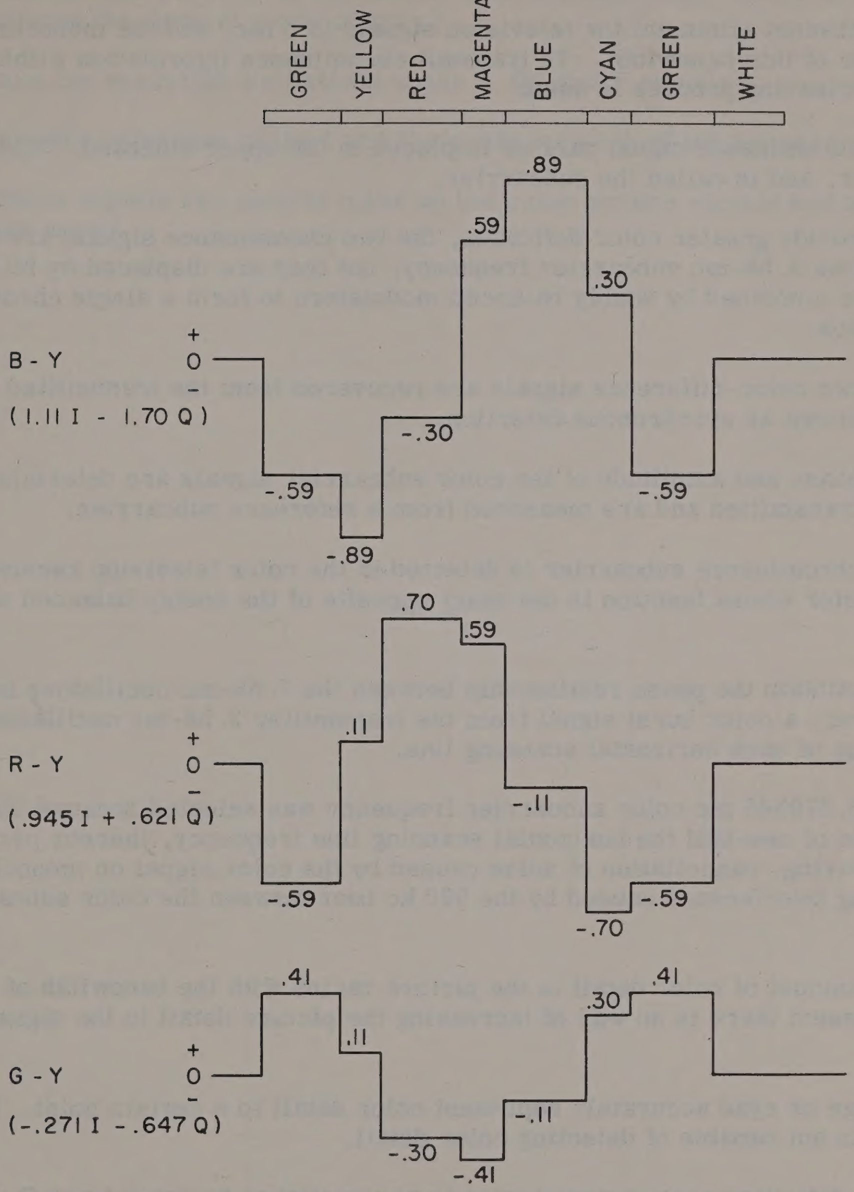


Figure 27. Color difference signals from I and Q matrix.

43. SUMMARY

a. The channel allotment for television signals is 6 mc, and the monochrome signal requires 5.35 mc of this bandwidth. To transmit chrominance information within this space, the frequency interleaving process is used.

b. The chrominance signal carrier is placed in the upper sideband, 3.58 mc from the picture carrier, and is called the subcarrier.

c. To provide greater color definition, the two chrominance signals are amplitude modulated at the same 3.58-mc subcarrier frequency, but they are displaced by 90 degrees. These two signals are combined by doubly balanced modulators to form a single chrominance signal for transmission.

d. The two color-difference signals are recovered from the transmitted single envelope by a process known as synchronous detection.

e. The phase and amplitude of the color subcarrier signals are determined by the particular color transmitted and are measured from a reference subcarrier.

f. The chrominance subcarrier is detected in the color television receiver by a synchronous detector whose function is the exact opposite of the doubly balanced modulators in the transmitter.

g. To maintain the phase relationship between the 3.58-mc oscillators in the transmitter and the receiver, a color burst signal from the transmitter 3.58-mc oscillator is transmitted at the beginning of each horizontal scanning line.

h. The 3.579545 mc color subcarrier frequency was selected because this frequency is an odd multiple of one-half the horizontal scanning line frequency, thereby permitting frequency interleaving, cancellation of noise caused by the color signal on monochrome receivers, and minimizing interference caused by the 920 kc beat between the color subcarrier and the sound signals.

i. The amount of color detail in the picture varies with the bandwidth of the transmitted signal. At present there is no way of increasing the picture detail in the signal with the 0.5 mc bandwidth.

j. Orange or cyan accurately represent color detail to a certain point. Beyond this point the eye is not capable of detecting color detail.

k. High-definition color transmission is accomplished by using I and Q chrominance axes. The I signal is 57 degrees from the reference subcarrier, and the Q signal is in quadrature with the I signal.

l. The I and Q signals, combined in quadrature, form the chrominance subcarrier signal to be transmitted. As the hue changes the chrominance subcarrier phase changes and amplitude varies with saturation.

m. The color signal in the receiver is converted to full-color kinescope representation by the use of I and Q demodulators.

44. REVIEW QUESTIONS

a. If the televised scene is colorless or gray, what type of output is produced by the color camera tubes?

b. If a monochrome receiver is tuned to a color transmission, what fully saturated primary color produces the darkest shade of gray?

c. What are the bandwidth limitations of the I, Q, and Y signals?

d. What are the polarities of the I and Q signals for each of the primary colors?

e. What three signals are used to make up the color picture signals and why are these particular colors used?

CHAPTER 4
COLOR TELEVISION RECEIVER FUNCTIONAL ANALYSIS

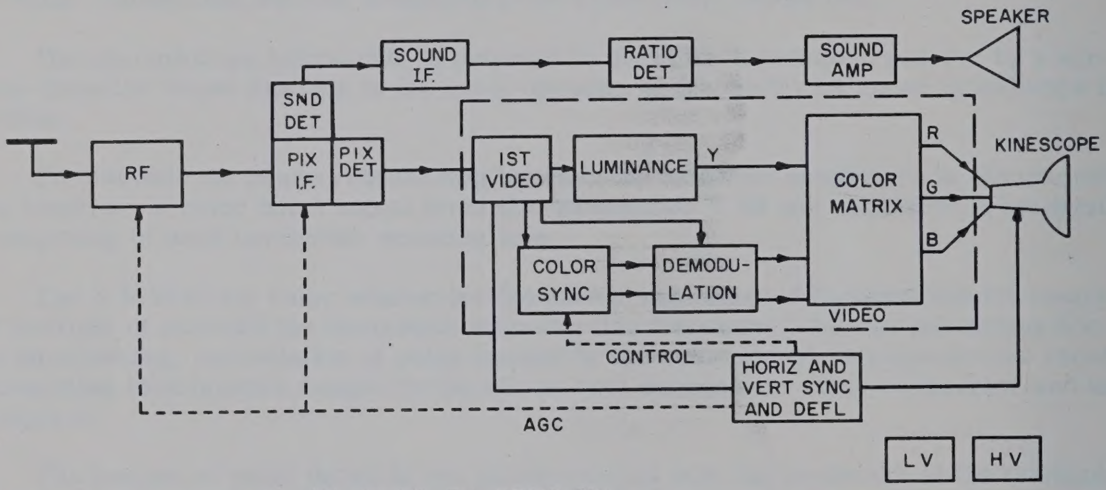
Section I. INTRODUCTION

45. GENERAL

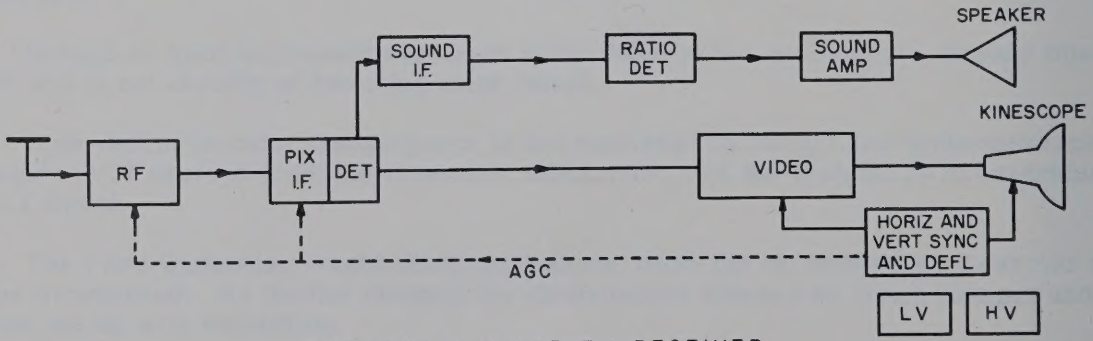
The basic circuits of a typical color television receiver are shown in block diagram form in this section. To simplify the discussion, only the differences that exist between a black-and-white and a color receiver are discussed in detail.

46. RECEIVER BLOCK DIAGRAM

a. Figure 28 is a block diagram which compares the basic sections of a color television receiver (A) to the basic sections of a monochrome receiver (B). The color receiver differs from the monochrome receiver only by the addition of the color synchronizing section, the demodulation (chrominance) section, and the matrix section. The luminance channel corresponds to the video channel section of the monochrome receiver and, therefore, is new in name only. The function of the luminance channel is to amplify the luminance information at the video second detector to a value suitable for application to the matrix (mixing) circuits. The chrominance section demodulates the color-difference information in the chrominance sidebands.


SPEAKER
SOUND I.F.
RATIO DET
SOUND AMP
SND DET
RF
PIX I.F.
PIX DET
IST VIDEO
LUMINANCE
Y
COLOR MATRIX
R
G
B
KINESCOPE
COLOR SYNC
DEMODULATION
VIDEO
CONTROL
HORIZ AND VERT SYNC AND DEFL
AGC
LV
HV

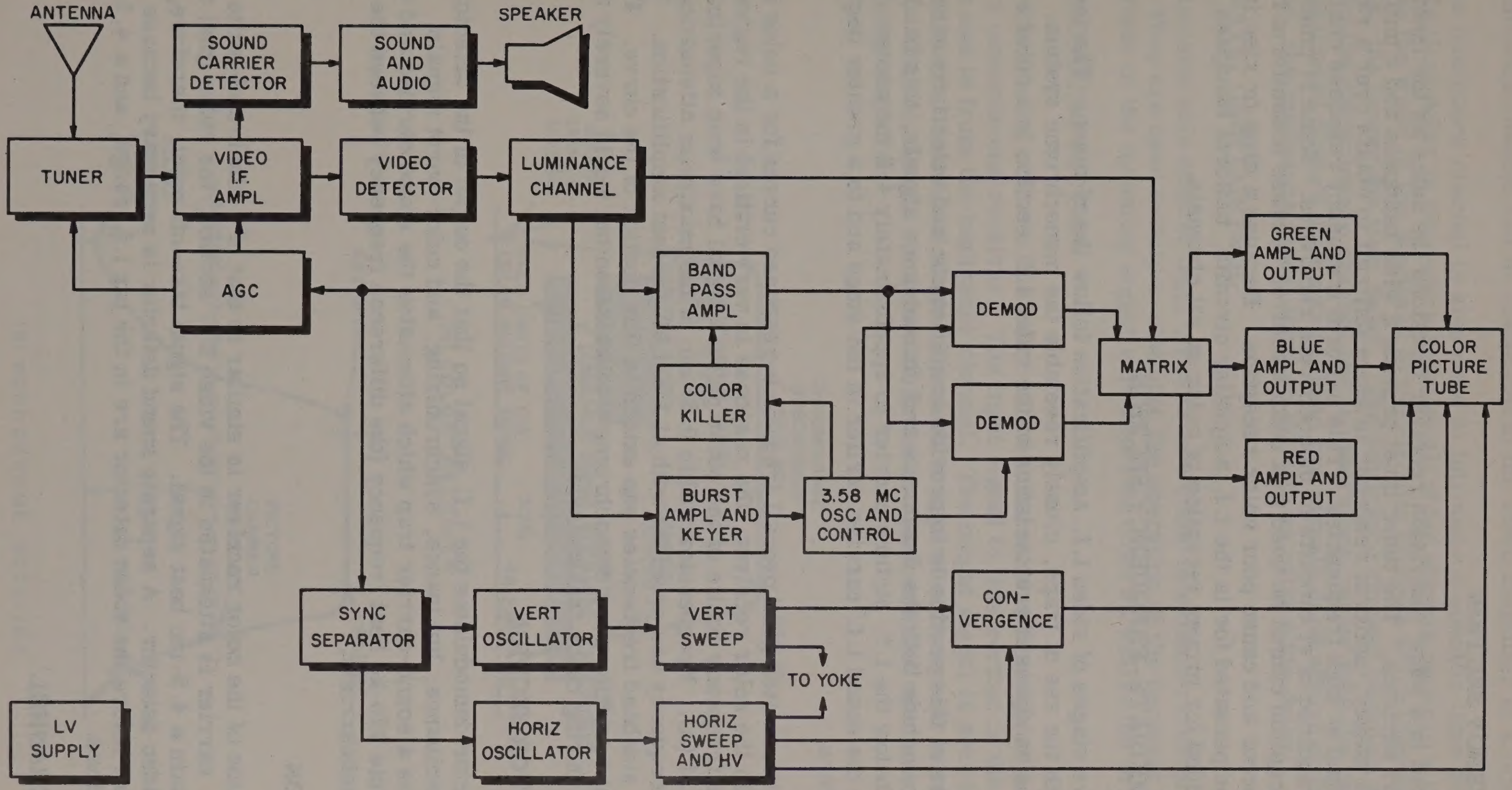
(A) COLOR TV RECEIVER


SPEAKER
SOUND I.F.
RATIO DET
SOUND AMP
KINESCOPE
RF
PIX I.F.
DET
VIDEO
HORIZ AND VERT SYNC AND DEFL
AGC
LV
HV

(B) BLACK & WHITE TV RECEIVER

Figure 28. Block diagrams of a color and a monochrome receiver.

b. Figure 29 is a detailed block diagram of a color television receiver. The sections used only in color receivers are unshaded. The shaded sections represent those also used in monochrome receivers. All of these sections are discussed in this chapter, except those concerned with deflection and convergence which are discussed in another chapter.


ANTENNA
TUNER
SOUND CARRIER DETECTOR
SOUND AND AUDIO
SPEAKER
VIDEO I.F. AMPL
VIDEO DETECTOR
LUMINANCE CHANNEL
AGC
BAND PASS AMPL
COLOR KILLER
BURST AMPL AND KEYER
3.58 MC OSC AND CONTROL
DEMOD
DEMOD
MATRIX
GREEN AMPL AND OUTPUT
BLUE AMPL AND OUTPUT
RED AMPL AND OUTPUT
COLOR PICTURE TUBE
SYNC SEPARATOR
VERT OSCILLATOR
VERT SWEEP
TO YOKE
CON-VERGENCE
HORIZ OSCILLATOR
HORIZ SWEEP AND HV
LV SUPPLY

NOTE: SECTIONS SIMILAR TO THOSE USED IN MONOCHROME RECEIVERS ARE SHADED.

SECTIONS USED ONLY IN COLOR RECEIVERS ARE UNSHADED.

Figure 29. Detailed block diagram of a color receiver.

Section II. GENERAL BLOCK DIAGRAM ANALYSIS

47. RADIO-FREQUENCY SECTION

The rf tuner used in a color television receiver functions the same as the tuner found in many monochrome rf sections. The tuner must provide a wide bandpass and a uniform frequency response. A steady, uniform response is more difficult to obtain over a range of 6 mc at low frequencies than at high frequencies. This uniform frequency response characteristic is not necessarily required of rf circuits in monochrome receivers. Some rf tuners designed for monochrome reception cannot be used in a color receiver because nonuniform frequency amplification may occur and cause poor color reception. Because a drop or rise in the rf tuner response may be compensated for in the i.f. amplifier circuits, uniform bandpass characteristics must be provided for proper reception of color on all channels.

48. VIDEO INTERMEDIATE-FREQUENCY SECTION

a. Four or five stages of video i.f. amplification follow the rf tuner. The individual stages, together with the use of traps, closely resemble the monochrome system. The major difference is that the bandpass characteristics of the video i.f. section in a color receiver are more restrictive.

b. The purpose of this section is to provide amplification and selectivity over a specific frequency band. To include both the luminance and chrominance signals, this band should extend from 0.75 mc below the i.f. picture carrier to approximately 4.2 mc above. This section also attenuates the sound i.f. carrier earlier in the stage and to a greater degree than in monochrome receivers.

c. Figure 30 illustrates good overall frequency-response curves for a color and a monochrome receiver. In the color receiver, the response is very critical in the region of the sound carrier. The frequency limits of the color picture signal have been superimposed on the response curve of (A). Frequencies within 0.35 mc of the maximum attenuation point of the sound-carrier frequency are provided with at least 90-percent amplification. Thus, the chroma subcarrier sideband frequencies can extend to this portion of the curve. The frequency response in (B) would produce good monochrome transmission but would severely attenuate the chrominance signal during color transmission.

49. VIDEO DETECTOR SECTION

The video detector demodulates the i.f. signal so that the output of the detector circuit consists of the chrominance, luminance, synchronizing, and color-burst signals. The input circuit often contains a sound-carrier trap which attenuates the sound carrier and provides against an undesirable 920-kc beat frequency (the difference frequency between the sound carrier and the color subcarrier).

50. SOUND SECTION

The sound section of the color receiver is similar to that of a black-and-white receiver. Since the sound i.f. carrier is attenuated in the video i.f. section, the video (pix) detector output does not contain a 4.5-mc beat signal. The signal take-off point, therefore, must be placed before the video detector. A separate sound detector is necessary because the signals available at any point before the video detector are in the pix i.f. range, and a 4.5-mc sound signal must be obtained.

51. LUMINANCE CHANNEL

a. The amplification of the luminance portion of the video signal is the main function of the luminance channel. Since this video signal represents the brightness variations of the image, the luminance channel can be compared to the video amplifier of a monochrome receiver.

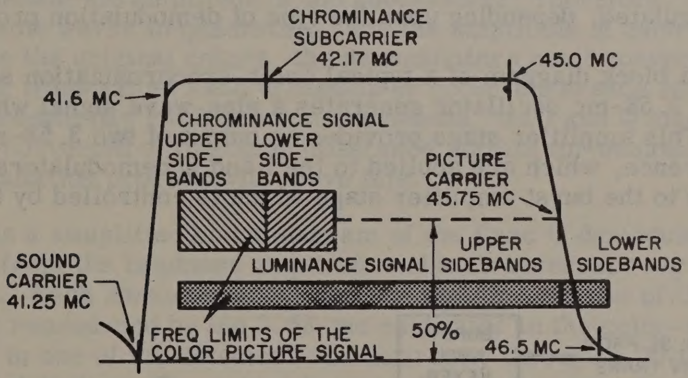
b. The luminance channel is also used to introduce a specific time delay in the brightness signal. This time delay is necessary because all video signals undergo a time delay in reverse proportion to the width of the bandpass of the circuits through which they pass. The narrower the bandpass, the longer the time delay. The luminance channel passes a wider range of frequencies than the chrominance channel and is, therefore, wider than the chrominance channel. Since the associated picture elements of these two signals must arrive at the picture tube simultaneously, the luminance signal must go through an extra time delay.

52. AUTOMATIC GAIN CONTROL

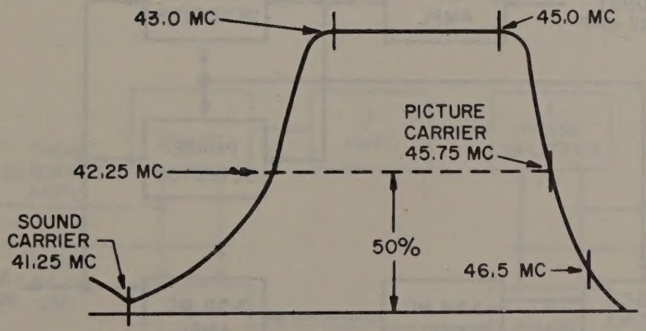
The automatic gain control (agc) circuits in a color television receiver are conventional in operation. They are used mainly to stabilize the operation of the receiver when the variations in the amplitude of the incoming signal will affect the color as well as the brightness of the image.

53. SYNCHRONIZING SECTION

The synchronizing circuits in a color television receiver function in the same manner as do those in a monochrome receiver. The input signal to this section is the same as that to the agc circuits and is from the luminance channel. The output signal is sent to the horizontal and vertical oscillators. Individual stages are used to separate the synchronizing pulses from the video signal. This section is composed of horizontal and vertical synchronizing separators and a synchronizing amplifier.


CHROMINANCE SUBCARRIER 42.17 MC
45.0 MC
41.6 MC
CHROMINANCE SIGNAL
UPPER SIDE-BANDS
LOWER SIDE-BANDS
PICTURE CARRIER 45.75 MC
UPPER SIDEBANDS
LOWER SIDEBANDS
LUMINANCE SIGNAL
SOUND CARRIER 41.25 MC
FREQ LIMITS OF THE COLOR PICTURE SIGNAL
50%
46.5 MC

(A) COLOR RECEIVER


43.0 MC
45.0 MC
PICTURE CARRIER 45.75 MC
42.25 MC
SOUND CARRIER 41.25 MC
50%
46.5 MC

(B) MONOCHROME RECEIVER

Figure 30. Rf and i.f. response curves.

Section III. COLOR SECTION BLOCK DIAGRAM ANALYSIS

54. INTRODUCTION

In the previous section, the stages discussed were common to both color and monochrome television receivers. However, many of the stages between these and the color picture tube are entirely different from those in a black-and-white receiver. The stages peculiar to the color receiver are described in this section.

55. BANDPASS AMPLIFIER

The composite color signal, which is composed of the chrominance, luminance, burst, synchronizing, and blanking signals, is applied to the bandpass amplifier from the first video amplifier. The bandpass amplifier separates the chrominance signal from the composite color signal and applies it to the demodulators. Thus, the output of the bandpass amplifier consists of only the chrominance signal. All other signals included in the composite color signal are either channeled to other circuits or attenuated.

56. COLOR SYNCHRONIZING SECTION

a. The 3.58-mc chrominance subcarrier, which was cancelled out in the doubly balanced modulators in the transmitter, must be reinserted in the receiver for proper color reproduction. To recover the color-difference signals in the receiver, the modulation process must be reversed. The locally generated 3.58-mc cw reference signal is applied to the demodulators along with the signals from the bandpass amplifiers. The frequency and phase of the 3.58-mc reference signal is regulated, depending upon the type of demodulation process used.

b. Figure 31 is a block diagram of a typical color-synchronization section feeding I and Q demodulators. The 3.58-mc oscillator generates a sine-wave signal which is amplified in the following stage. This amplifier stage provides an output of two 3.58-mc signals, having a 90-degree phase difference, which are applied to the I and Q demodulators. The composite color signal is applied to the burst amplifier stage which is controlled by the keying stage.

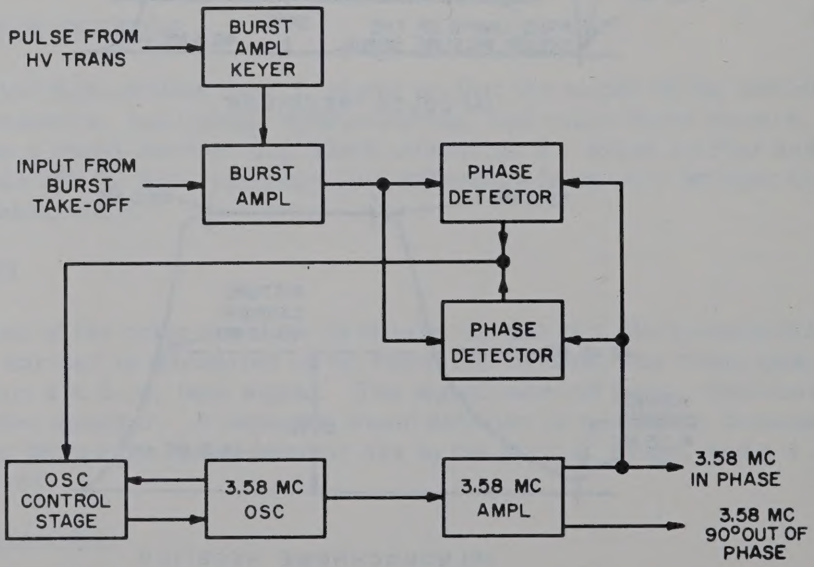


Figure 31. Color sync circuit.

The keyer stage permits the burst amplifier to conduct only during horizontal-retrace time. The output of the burst amplifier contains only the color burst signal. The color burst and in-phase 3.58-mc signals regulate the frequency and phase of the demodulator signals.

57. COLOR-KILLER SECTION

The purpose of the color-killer circuits in a color television receiver is to prevent any video information from passing through the bandpass amplifier and subsequent circuits when black-and-white transmissions are applied to the receiver. This circuit operates in the same manner as an agc amplifier to prevent any signal other than the luminance signal from reaching the output. The color killer is controlled by a bias voltage obtained from the phase discriminator. When monochrome signals are being transmitted, very little bias is developed in the phase discriminator. This causes the color killer to operate at high gain and drives the bandpass amplifier to cut off. The time constant of the bandpass amplifier input circuit is long enough to hold it below cut off during the horizontal input.

58. I AND Q DEMODULATION METHOD

a. The output of the bandpass amplifier consists only of the chrominance signal which varies in both amplitude and phase. This chrominance signal is coupled to the demodulator stages which detect the difference between the phase and the amplitude of the chrominance signal.

b. Detection of both amplitude and phase is necessary because the chrominance signal is composed of an in-phase signal and another signal which is 90 degrees out of phase. Both of these signals modulate the amplitude of the subcarrier. Therefore, the chrominance signal consists of two sine waves in quadrature, and the amplitude of each is separately modulated. To reproduce the original colors, the demodulators must convert the chrominance signal into either the transmitted I and Q signals or color-difference signals other than the I and Q signals. In present day color television systems, the I and Q signals are transmitted; however, these are converted to the color difference signals for demodulation. A discussion of the I and Q demodulation process will prove this.

c. Figure 32 is a simplified block diagram of the I and Q demodulation process. The chrominance signal from the bandpass amplifier and a cw reference signal are applied to the I and Q demodulators. Each demodulator is arranged to recover one of the color signals. The subcarrier signal is reproduced by the 3.58-mc oscillator in the color-synchronizing section and applied directly to one of the detectors and indirectly through a 90-degree phase-shifting network to the other detector. The output from each detector depends on the relative phase between the reinserted 3.58-mc subcarrier and the chrominance signal. Each detector recovers the chrominance signal that is either in phase or 180 degrees out of phase with the reinserted 3.58-mc subcarrier applied to that detector and ignores the other quadrature signal.

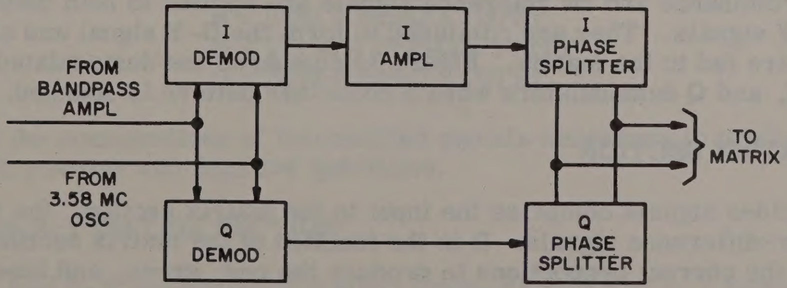


Figure 32. I and Q demodulation process.

d. The output of the Q demodulator is fed to a phase splitter which provides the required positive and negative signals for the matrix. Since the I signal is transmitted by means of vestigial sideband, the detected signal amplitude is lower than the Q signal, thus the requirement for an additional stage of amplification. Also, a delay is introduced into the I signal channel so that it will have the proper time reference to the luminance and Q signals. From the I amplifier the I signal is applied to a phase splitter which furnishes the required positive and negative signals needed by the matrix.

59. R-Y AND B-Y DEMODULATION METHOD

a. Since it is necessary for the receiver to convert the I and Q signals to R-Y and B-Y signals before the R, G, and B signals can be developed, it is more advantageous for color television receivers to recover the R-Y and B-Y signals than the I and Q signals. The advantage in recovering the R-Y and B-Y signals is that fewer stages and components are required than are needed for the I and Q signals. Generally, this type of modulation may be obtained if the c-w reference signals have specific phase relationships with the color burst. Figure 22 shows that the reference signal used to recover the B-Y signal is in phase with the zero-reference axis and that the reference signal used to recover the R-Y signal is displaced 90 degrees. The phase angles between the I and the R-Y vector and between the Q and B-Y vector are each 33 degrees.

b. Figure 33 is a simplified block diagram of the R-Y and B-Y demodulation process. The operation of this circuit is similar to that of the I and Q demodulators except for the difference in the phase angle of the cw reference signals. This phase difference results from the difference in phase between the I and Q signals and the color difference signals. This results in output signals which are different from those of the I and Q demodulators, because the chrominance signal is detected with respect to different reference signals.

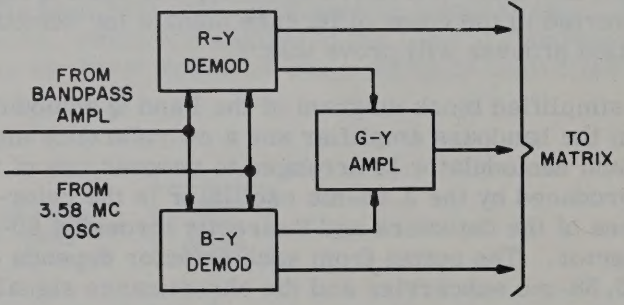


Figure 33. R-Y and B-Y demodulation process.

c. The chrominance and cw reference signals are applied to both detectors. The outputs are R-Y and B-Y signals. They are combined to form the G-Y signal and all three color difference signals are fed to the matrix. Figure 34 compares the demodulated output signals of the R-Y, B-Y, I, and Q demodulators when a color-bar pattern is scanned.

60. I AND Q MATRIX SECTION

a. Three video signals comprise the input to the matrix section: the luminance signal and the two color-difference signals. It is the function of the matrix section to combine these three signals in the correct proportions to produce the red, green, and blue color signals.

b. In I and Q demodulation, the Y, I, and Q signals each contain a portion of the original red, blue, and green color signals. An expression for each of the transmitted signals can be

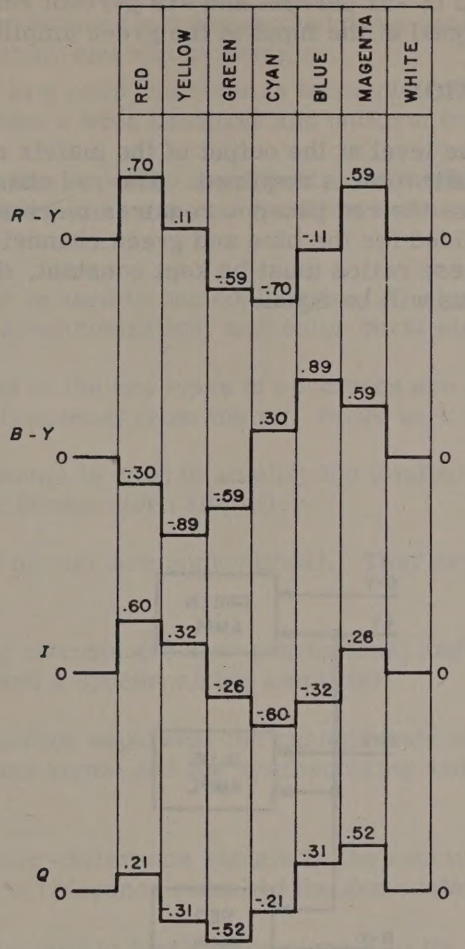


Figure 34. Comparison of R-Y, B-Y, I, and Q signals.

obtained in terms of the original color signals.

$$Y = 30\%R + 59\%G + 11\%B$$
$$I = 60\%R - 28\%G - 32\%B$$
$$Q = 21\%R - 52\%G + 31\%B$$

From these equations, the color signals can be shown in terms of the transmitted signals:

$$R = 96\%I + 63\%Q + 100\%Y$$
$$B = 111\%I + 172\%Q + 100\%Y$$
$$G = 28\%I - 64\%Q + 100\%Y$$

It can be seen that the combinations of transmitted signals necessary to produce the color signals consist of both positive and negative quantities.

61. G-Y, B-Y, and R-Y MATRIX SECTION

Since the R-Y and B-Y demodulation method produces R-Y and B-Y signals, the matrix section is simpler than that used for the I and Q signals. An R-Y signal and a positive Y signal (fig. 35) are combined at the input to the red amplifier, and a B-Y signal and a positive Y signal are combined at the input to the blue amplifier. A G-Y signal is formed by combining R-Y and B-Y signals in the ratio of -51 percent and -19 percent respectively. This G-Y signal is combined with a positive Y signal at the input to the green amplifier.

62. OUTPUT AMPLIFIER SECTION

In some color receivers, the level at the output of the matrix may not be sufficient to drive the kinescope, and voltage amplification is required. The red channel amplifier is allowed to operate at maximum gain because the red phospor requires more signal voltage than the blue and green. Gain controls, provided for the blue and green channels, allow any ratio of blue to green to red to be obtained. These ratios must be kept constant, despite tube aging, so that the light output of all phosphorous will be equal.

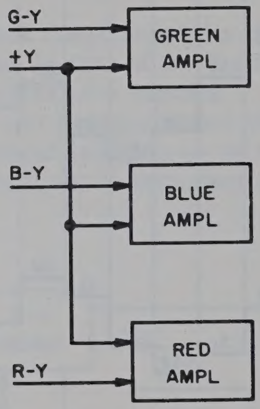


Figure 35. Matrix section.

Section IV. SUMMARY AND REVIEW

63. SUMMARY

a. The color receiver differs from the monochrome receiver only by the addition of color synchronization, demodulation, and matrix sections.

b. The rf tuner used in a color receiver is the same rotary-drum type used in a monochrome receiver. It provides a wide bandpass and uniform frequency response.

c. The video i.f. section provides amplification and selectivity for a particular frequency band. The bandpass characteristics are more critical for a color receiver than for a monochrome receiver.

d. The video detector is used to demodulate the i.f. signal. The output consists of the chrominance, luminance, synchronization, and color burst signals.

e. The sound sections of the two types of receivers are similar. A sound detector is necessary to increase the frequency from the i.f. range to 4.5 mc.

f. The luminance channel is used to amplify the luminance portion of the video signal and is comparable to the monochrome video amplifier.

g. The circuits used for agc are conventional. They are used mainly to stabilize amplitude variations.

h. The synchronizing circuits are also conventional and consist of horizontal and vertical synchronizing separators and a synchronizing amplifier.

i. The bandpass amplifier separates the chrominance signal from the composite color signal, blocks the luminance signal and the synchronizing and blanking pulses, and keys out the color burst.

j. To recover the color-difference signals in the receiver, the chrominance signal is applied with the 3.58-mc cw reference signal to the demodulators.

k. The color killer is used to block video signals to the bandpass amplifier during monochrome reception.

l. The two types of demodulation used in color television receivers are the I and Q type and the R-Y and B-Y type. The two differ mainly in the comparative phase of the reference signals to the color burst.

m. The output signals of these two types of demodulator circuits also pass through different matrix sections. The R-Y and B-Y signals can be fed directly to the red, green, and blue amplifiers, but the feeding of the I and Q signals to these amplifiers is a complex operation.

n. Color signal amplifiers are necessary at the output to raise the low-level matrix output.

64. REVIEW QUESTIONS

a. What are the basic requirements for an rf tuner used in a color receiver? Explain.

b. Why is a sound i.f. detector used in a color receiver?

c. How is the correct frequency and phase of the 3.58-mc reference signal obtained?

d. What is the phase relationship between the two cw reference signals developed in the synchronizing circuit?

e. How does the cw reference signal that is applied to the I demodulator differ from that applied to the Q demodulator? How do the R-Y and B-Y reference signals differ from each other?

CHAPTER 5

COLOR TELEVISION RECEIVER CIRCUITS

Section I. INTRODUCTION

65. GENERAL

This chapter provides a detailed circuit analysis of the circuits found in a typical color television receiver. Only the demodulator and matrix sections differ from the circuits which were examined in block diagram form in the preceding chapter. In the following sections, if reference is not made to a schematic diagram for a particular circuit, the discussion is based on the schematic diagram of the entire color television receiver (fig. 36).

66. THE COLOR SIGNAL

Before discussing the receiver circuits, a brief review of the color signal may prove of value. Information is transmitted with the picture portion of the signal to convey the color (hue and saturation) of a scene. Signals proportional to the brightness of the scene are transmitted as in black-and-white operation. The chrominance signal is combined with the luminance signal in the sidebands of a two-phase, modulated, suppressed subcarrier whose phase indicates hue and whose amplitude is proportional to the degree of saturation. The absence of the chrominance signal indicates that there is no color, and only blacks, shades of gray, or whites will be reproduced.

Section II. LUMINANCE SECTION CIRCUIT ANALYSIS

67. ANTENNA MATCHING UNIT

The antenna matching unit in figure 36 includes an fm trap. Where interference is encountered from a strong fm signal, the trap can be tuned by adjusting L5 until the interference is at a minimum. In some receivers, the fm trap may tune into channel 6 or even into channel 5. Therefore, caution should be exercised if these channels are used, since adjusting the fm trap into these channels will greatly reduce sensitivity.

68. RF SECTION

a. In the rf section shown in figure 37, two different rf tuner combinations are possible: a vhf alone or a combined vhf and uhf arrangement. The vhf tuner uses a 13-position switch to provide the 12 vhf channels, a 6BQ7A rf amplifier, and a 6X8 mixer oscillator. When switched to the uhf position, this tuner serves as an i.f. amplifier. The uhf tuner uses a 6AF4A oscillator and a 1N82 silicon crystal diode mixer.

b. When the tuner unit (fig. 37) is used in the vhf ranges (channels 2 to 13), the 6BQ7A is operated as a grounded-grid rf amplifier. The output of the rf amplifier is fed to the control grid of the pentode section of the 6X8, which is used as the mixer tube. The local oscillator is of the Colpitts type and uses the triode section of the 6X8. In a Colpitts circuit, feedback voltage is obtained by tapping the grid and cathode across a portion of the tuned circuit. Output from the oscillator is fed to the mixer which combines the oscillator and rf amplifier output. The resulting intermediate frequency is in the 41-mc range and is coupled to the picture i.f. stages through transformer T2.

c. When operating in the uhf ranges, the signal from the antenna is fed into a double-tuned preselector circuit. A 1N82 low-noise crystal mixer converts the combined rf signal and the 6AF4 oscillator output signal to a 41-mc i.f. signal for amplification in the i.f. system. The uhf oscillator operates at fundamental frequency throughout the uhf range. That is, it does not depend upon a harmonic of the fundamental frequency of the oscillator. This prohibits spurious harmonic emission.

CHAPTER 5

COLOR TELEVISION RECEIVER CIRCUITS

Section I. INTRODUCTION

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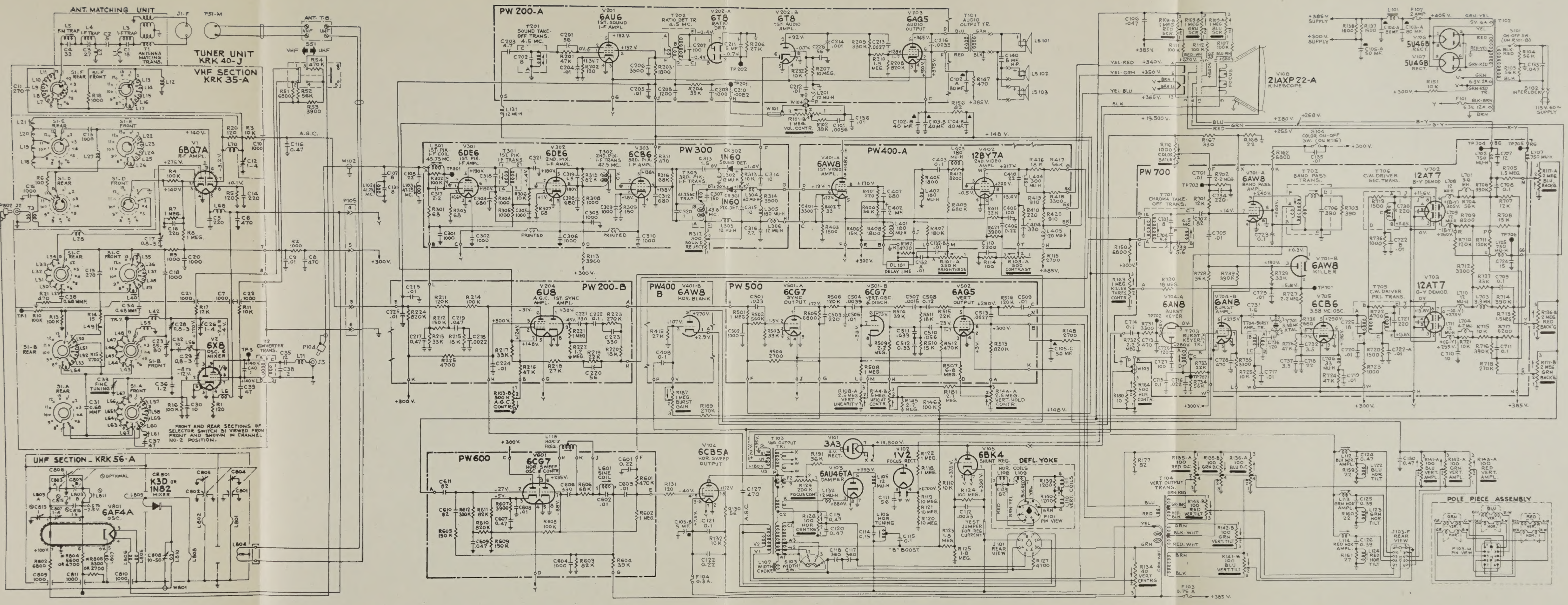

ANT. MATCHING UNIT
TUNER UNIT KRK 40-J
VHF SECTION KRK 35-A
6BQ7A R.F. AMPL.
6X8 OSC. MIXER
FRONT AND REAR SECTIONS OF SELECTOR SWITCH S1 VIEWED FROM FRONT AND SHOWN IN CHANNEL NO. 2 POSITION.
UHF SECTION - KRK 56-A
K3D OR 1N82 MIXER
6AF4A OSC.
PW 200-A
6AU6 1ST. SOUND I-F AMPL.
6T8 RATIO DET.
6T8 1ST. AUDIO AMPL.
6AQ5 AUDIO OUTPUT
PW 300
6DE6 1ST. PIX. I-F AMPL.
6DE6 2ND. PIX. I-F AMPL.
6CB6 3RD. PIX. I-F AMPL.
1N60 SOUND DET.
1N60 PIX. DET.
PW400-A
6AW8 1ST. VIDEO AMPL.
12BY7A 2ND. VIDEO AMPL.
DL 101 DELAY LINE
PW 200-B
6U8 A.G.C. AMPL. 1ST. SYNC AMPL.
PW400 B
6AW8 HOR. BLANK
PW 500
6CG7 SYNC OUTPUT
6CG7 VERT. OSC & DISCH
6AQ5 VERT. OUTPUT
PW600
6CG7 HOR. SWEEP OSC & CONTR.
6CB5A HOR. SWEEP OUTPUT
3A3 H.V. RECT.
6AU4GTA DAMPER
1V2 FOCUS RECT.
6BK4 SHUNT REG.
DEFL. YOKE
21AXP22-A KINESCOPE
5U4GB RECT.
5U4GB RECT.
PW 700
6AW8 BAND PASS AMPL.
12AT7 B-Y DEMOD
6AW8 KILLER
12AT7 G-Y DEMOD
6AN8 BURST KEYER
6AN8 BURST AMPL.
6CB6 3.58 MC OSC.
POLE PIECE ASSEMBLY
115 V. 60~ SUPPLY
+385 V. SUPPLY
+300 V. SUPPLY

Figure 36. Overall schematic diagram of a color receiver.

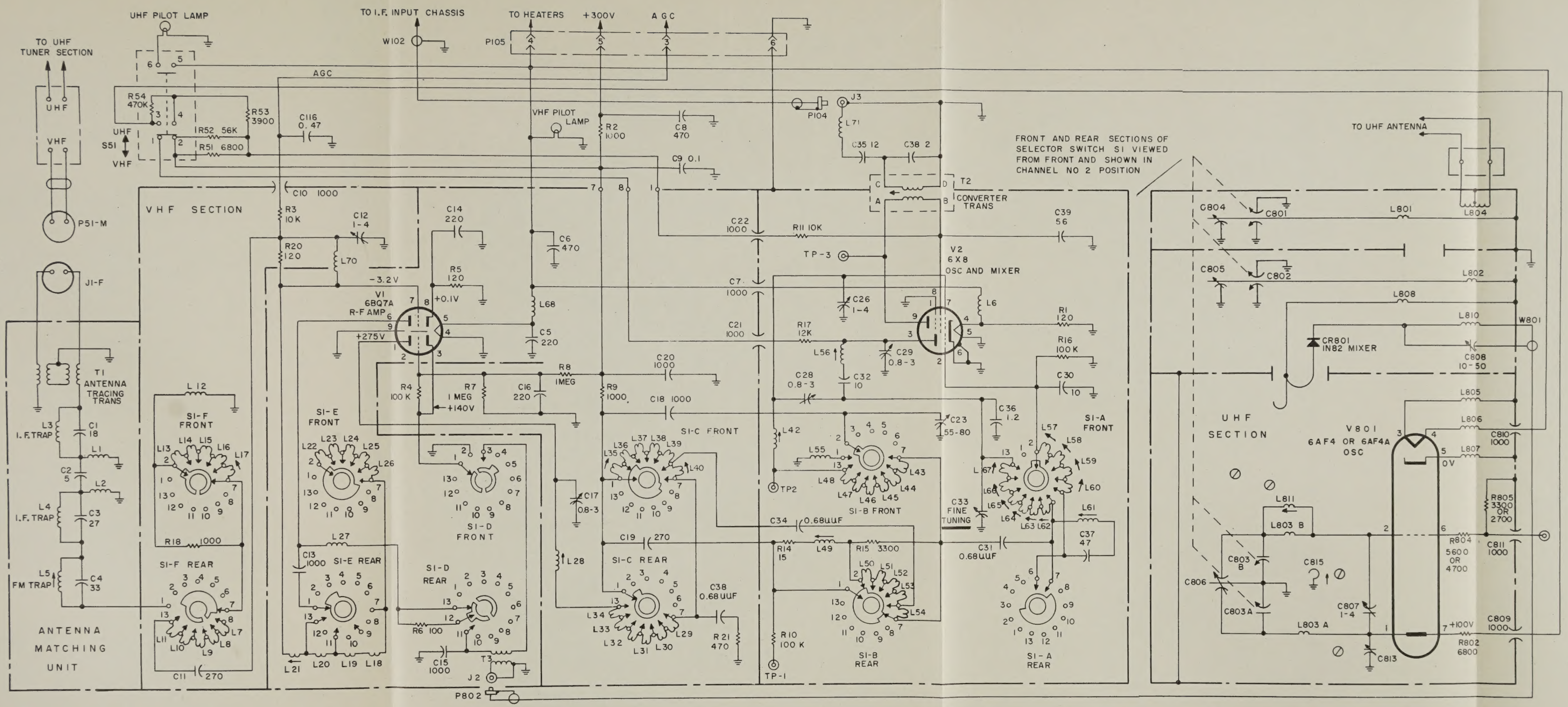

TO UHF TUNER SECTION
UHF
VHF
P51-M
J1-F
UHF PILOT LAMP
6
5
R54 470K
3
4
R53 3900
UHF
S51
VHF
1
2
R52 56K
R51 6800
C116 0.47
AGC
TO I.F. INPUT CHASSIS
W102
P105
TO HEATERS
+300V
AGC
4
5
3
6
VHF PILOT LAMP
R2 1000
C8 470
C9 0.1
P104
J3
L71
C35 12
C38 2
T2
CONVERTER TRANS
C
D
A
B
FRONT AND REAR SECTIONS OF SELECTOR SWITCH S1 VIEWED FROM FRONT AND SHOWN IN CHANNEL NO 2 POSITION
TO UHF ANTENNA
C10 1000
7
8
1
VHF SECTION
R3 10K
C12 1-4
R20 120
L70
C14 220
C6 470
R5 120
-3.2V
+0.1V
V1 6BQ7A R-F AMP
+275V
L68
C5 220
C22 1000
R11 10K
C39 56
TP-3
V2 6X8 OSC AND MIXER
C7 1000
C21 1000
C26 1-4
R17 12K
L56
C29 0.8-3
L6
R1 120
R16 100K
C28 0.8-3
C32 10
C30 10
T1 ANTENNA TRACING TRANS
L3 I.F. TRAP
C1 18
L1
C2 5
L2
L4 I.F. TRAP
C3 27
L5 FM TRAP
C4 33
ANTENNA MATCHING UNIT
L12
S1-F FRONT
L13 L14 L15 L16 L17
R18 1000
S1-F REAR
L11 L10 L9 L8 L7
C11 270
S1-E FRONT
L22 L23 L24 L25 L26
L27
C13 1000
S1-E REAR
L21 L20 L19 L18
R4 100K
R7 1 MEG
+140V
R8 1MEG
C16 220
C20 1000
R9 1000
C18 1000
S1-D FRONT
S1-D REAR
R6 100
C15 1000
T3
J2
P802
C17 0.8-3
L28
S1-C FRONT
L35 L36 L37 L38 L39 L40
C19 270
S1-C REAR
L34 L33 L32 L31 L30 L29
C38 0.68UUF
R21 470
L42
TP2
L55
L48 L47 L46 L45 L44 L43
S1-B FRONT
C34 0.68UUF
R14 15
L49
R15 3300
L50 L51 L52 L53 L54
R10 100K
TP-1
S1-B REAR
C36 1.2
C23 55-80
C33 FINE TUNING
L57 L58 L59 L60
L67 L66 L65 L64 L63 L62
S1-A FRONT
L61
C37 47
C31 0.68UUF
S1-A REAR
C804
C801
L801
L804
C805
C802
L802
L808
L810
W801
CR801 IN82 MIXER
C808 10-50
L805
L806
C810 1000
UHF SECTION
V801 6AF4 OR 6AF4A OSC
L807
0V
L811
L803 B
C803 B
C815
C806
C803 A
C807 1-4
L803 A
C813
R805 3300 OR 2700
R804 5600 OR 4700
C811 1000
+100V
C809 1000
R802 6800

Figure 37. Rf tuner section.

d. Wide band performance and uniform flat response on all channels are essential for good performance in color television. Figure 38 shows four possible response curves from an rf tuner. The response curve necessary for good color reception is shown in figure 38(A). The other response curves would cause distortion in a color receiver, although they may be satisfactory in monochrome reception. Poor color transition (change from one color to another) would be apparent in each case. In addition, the response shown in figure 38(B) would cause low color saturation, and the response shown in figure 38(C) would cause high color saturation. Since color transition normally occurs at the edges of an object, the transition usually depends on the higher color video frequencies.

69. VIDEO I. F. SECTION

a. The video i.f. section provides amplification and selectivity for a specific band of frequencies. The band extends from 4.2 mc above to 0.8 mc below the picture carrier frequency. The video i.f. section also serves to attenuate the sound carrier.

b. The video i.f. section shown in figure 39 consists of three video i.f. amplifier stages with stagger tuning, a crystal picture detector, and a crystal sound detector. The grid circuit of the first video i.f. amplifier stage is tuned to the picture carrier frequency (45.75 mc). L102 and C131 in the grid circuit form a trap which is tuned to 41.25 mc and used to attenuate the sound carrier. L103 and C108, also in the grid circuit, form a trap which is tuned to 47.25 mc and used to attenuate the sound carrier in the adjacent channel. The first picture i.f. transformer (T301) in the plate circuit is double-tuned, resulting in a 3.5-mc bandwith for this stage. The second picture i.f. transformer (T302) in the plate circuit of the second video i.f. amplifier is tuned to 42.5 mc. The third picture i.f. transformer (T303) contains a 41.25-mc sound trap and a bifilar transformer tuned to the approximate center of the i.f. frequency range (43.8 mc). R312 is a sound-reject control which can be adjusted to obtain maximum sound rejection in the signal being applied to the picture detector. The sound signal is coupled through crystal detector CR302 to the sound take-off transformer (T201). Crystal detector CR302 permits the sound signal to be supplied to the sound section without seriously impairing the gain of the signal.,

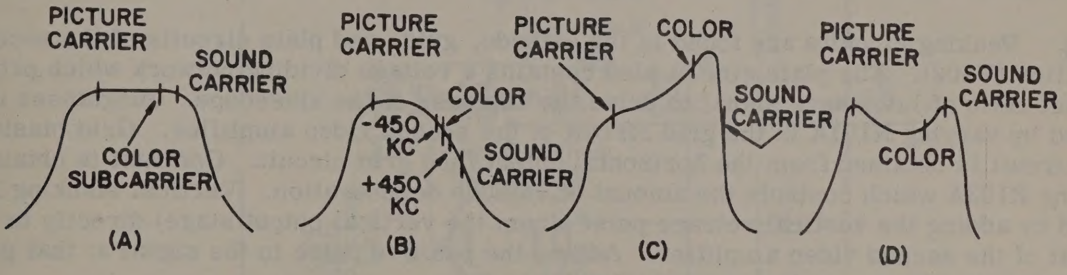


Figure 38. Rf tuner response curves.

70. SOUND SECTION

The sound section shown in figure 40 consists of a sound i.f. amplifier, a ratio detector, a first audio amplifier, and an audio output tube. The grid circuit of the sound i.f. amplifier (V201) contains the sound take-off transformer (T201) tuned to 4.5 mc and an RC noise filter. The sound signal is applied to the grid of the i.f. amplifier through the take-off transformer. The output of the i.f. amplifier is fed to the ratio detector (V202-A) through the ratio detector transformer T202, which is tuned to 4.5 mc. The ratio detector uses the duodiode section of the duodiode-triode. The triode stage of the duodiode-triode is used as the first stage of the audio amplification. R101B is the volume control. Transformer T101, which is in the plate circuit of the audio output tube, supplies a maximum of 3 watts of audio output to the 8-inch speaker. The cathode of the audio output tube develops 150 volts above ground, which provides a B-plus source for the sound i.f. amplifier, the third picture i.f. amplifier, the first synchronization amplifier stages, and the synchronization output stage. Because B-plus for the above stages is provided in this manner, a no-sound, no picture condition may result if the 6AQ5 audio output tube becomes inoperative.

71. LUMINANCE SECTION

a. The luminance section shown in figure 41 consists of the first and second video amplifier stages which amplify the composite color signal to the level at which the brightness portion of the signal is suitable for application to the kinescope. The color portion of the composite signal is then suitable for application to the color circuits.

b. The output from the picture detector (CR301) in the video i.f. section is applied to both the control grid and the cathode of the first video stage. The cathode circuit then provides luminance information to the control grid of the second video amplifier (V402) through the delay line (DL101). The plate circuit of this stage contains the chrominance take-off transformer (T701) which is located in the chrominance section. Synchronization and agc voltages are obtained from the primary of this transformer. The secondary provides chrominance information to the control grid of the bandpass amplifier (V701-A). The secondary also contains a 4.5-mc sound trap to prevent cross modulation between the sound carrier and the color subcarrier which would result in a 920-kc interference pattern in the picture.

c. The delay line is placed between the first and second video amplifier stages to delay the luminance information when receiving color transmissions so that both signals arrive at the kinescope at the same time. The luminance signal, which provides the very fine detail in a picture, has a wider bandwidth than the chrominance signal. The time delay required is inversely proportional to the bandwidth of the circuit.

d. Peaking circuits are found in the cathode, grid, and plate circuits of the second video amplifier (V402). The plate circuit also contains a voltage dividing network which provides the correct ratio of luminance signal to drive the cathodes of the kinescope. Brightness is controlled by varying R101A in the grid circuit of the second video amplifier. Grid biasing for this circuit is obtained from the horizontal output tube grid circuit. Contrast is obtained by varying R103A which controls the amount of cathode degeneration. Vertical blanking is obtained by adding the vertical retrace pulse (from the vertical output stage) directly to the plate circuit of the second video amplifier. Adding the positive pulse to the signal at that point blanks out the kinescope during vertical retrace time.

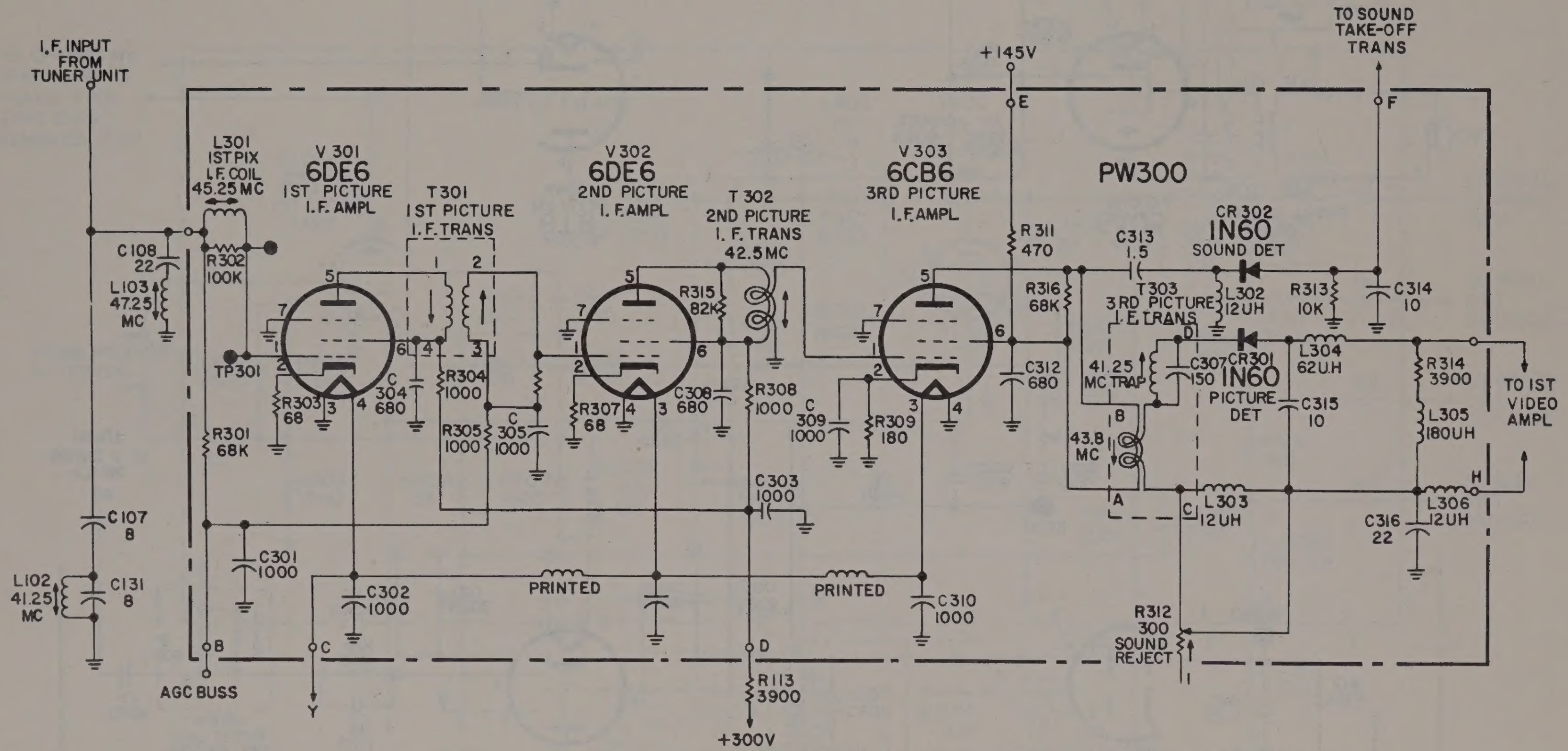

I.F. INPUT FROM TUNER UNIT
L301 1ST PIX I.F. COIL 45.25 MC
V 301 6DE6 1ST PICTURE I.F. AMPL
T301 1ST PICTURE I.F. TRANS
V 302 6DE6 2ND PICTURE I.F. AMPL
T 302 2ND PICTURE I.F. TRANS 42.5 MC
V 303 6CB6 3RD PICTURE I.F. AMPL
+145V
E
PW300
TO SOUND TAKE-OFF TRANS
F
C108 22
L103 47.25 MC
R302 100K
TP301
R303 68
C 304 680
R304 1000
R305 1000
C 305 1000
R301 68K
C107 8
L102 41.25 MC
C131 8
C301 1000
C302 1000
PRINTED
PRINTED
R315 82K
R307 68
C308 680
R308 1000
C 309 1000
R309 180
C303 1000
C310 1000
R311 470
R316 68K
C312 680
C313 1.5
CR 302 1N60 SOUND DET
T303 3RD PICTURE I.F. TRANS
L302 12UH
R313 10K
C314 10
41.25 MC TRAP
C307 150
CR301 1N60 PICTURE DET
L304 62UH
C315 10
43.8 MC
R314 3900
L305 180UH
L303 12UH
L306 12UH
C316 22
TO 1ST VIDEO AMPL
R312 300 SOUND REJECT
A
B
C
D
H
AGC BUSS
Y
R113 3900
+300V
1
2
3
4
5
6
7

Figure 39. Video i.f. section.

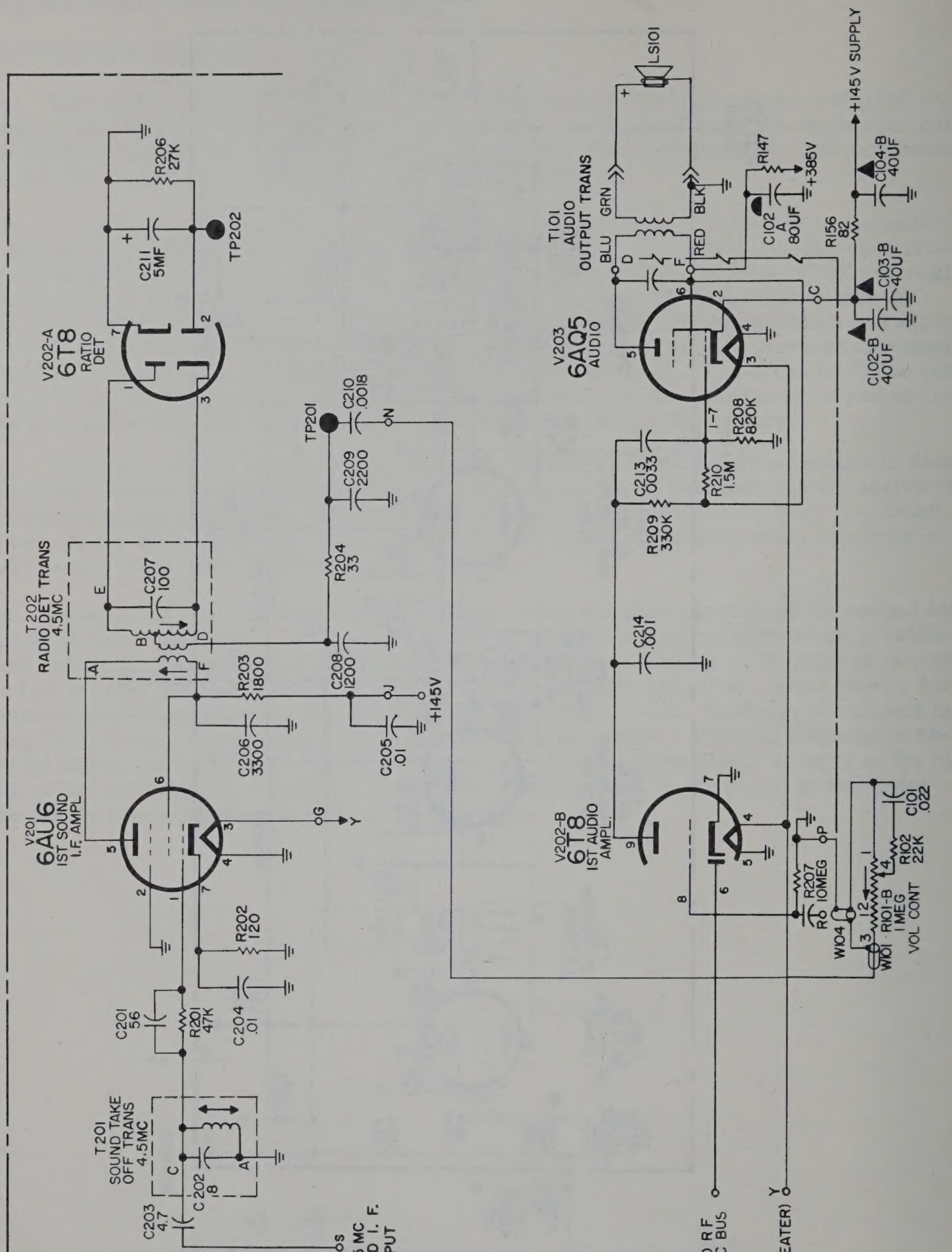

V201
6AU6
1ST SOUND
I.F. AMPL
T201
SOUND TAKE
OFF TRANS
4.5MC
C203
4.7
C 202
18
C201
56
R201
47K
C204
.01
R202
120
C206
3300
C205
.01
+145V
R203
1800
C208
1200
T202
RADIO DET TRANS
4.5MC
C207
100
R204
33
C209
2200
TP201
C210
.0018
V202-A
6T8
RATIO
DET
C211
5MF
TP202
R206
27K
4.5 MC
SOUND I. F.
INPUT
TO R F
AGC BUS
(HEATER)
V202-B
6T8
1ST AUDIO
AMPL.
R207
10MEG
W104
W101
R101-B
1 MEG
VOL CONT
R102
22K
C101
.022
C214
.001
R209
330K
C213
.0033
R210
1.5M
R208
820K
V203
6AQ5
AUDIO
T101
AUDIO
OUTPUT TRANS
BLU
GRN
RED
BLK
LS101
C102
A
80UF
R147
+385V
R156
82
C102-B
40UF
C103-B
40UF
C104-B
40UF
+145V SUPPLY

Figure 40. Sound section.

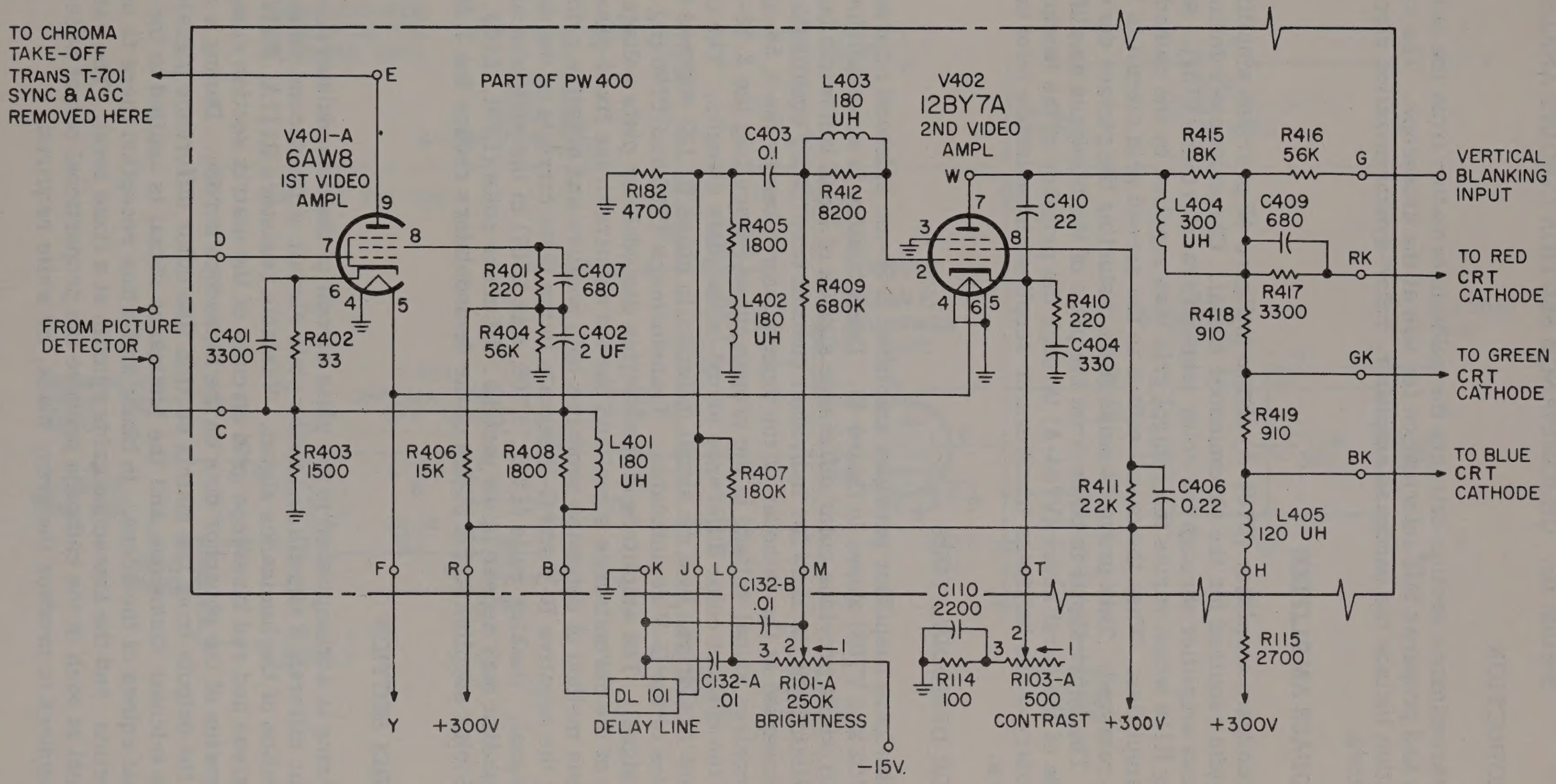

TO CHROMA TAKE-OFF TRANS T-701 SYNC & AGC REMOVED HERE
E
PART OF PW400
V401-A
6AW8
1ST VIDEO AMPL
FROM PICTURE DETECTOR
D
C
C401 3300
R402 33
R403 1500
R401 220
C407 680
R404 56K
C402 2 UF
R406 15K
R408 1800
L401 180 UH
R182 4700
C403 0.1
R405 1800
L402 180 UH
L403 180 UH
R412 8200
R409 680K
R407 180K
V402
12BY7A
2ND VIDEO AMPL
W
C410 22
R410 220
C404 330
R411 22K
C406 0.22
R415 18K
L404 300 UH
R416 56K
C409 680
R417 3300
R418 910
R419 910
L405 120 UH
R115 2700
G
RK
GK
BK
H
VERTICAL BLANKING INPUT
TO RED CRT CATHODE
TO GREEN CRT CATHODE
TO BLUE CRT CATHODE
F
R
B
K
J
L
M
T
C132-B .01
C132-A .01
C110 2200
R101-A 250K BRIGHTNESS
R114 100
R103-A 500 CONTRAST
DL 101 DELAY LINE
Y
+300V
+300V
+300V
-15V.

Figure 41. Luminance section.

Section III. CHROMINANCE SECTION CIRCUIT ANALYSIS

72. INTRODUCTION

The chrominance section extracts the color information from the color subcarrier and its sidebands and prepares this information for use at the kinescope. The circuits in the chrominance section include the bandpass amplifier, color-synchronization circuit, and the color demodulators.

73. BANDPASS AMPLIFIER

The bandpass amplifier (V701-A) shown in figure 42 provides amplification and maintains the bandwidth required for the chrominance signal. Chrominance information is supplied to the bandpass amplifier through the color take-off transformer (T701). Saturation is controlled by varying R116 which varies the control grid bias supplied by the cathode of the horizontal blanking amplifier. When the on-off switch in the screen grid circuit is in the off position, the B-plus is removed. This prevents noise from distorting the picture during monochrome transmission. The burst signal is taken from the plate of the bandpass amplifier and is coupled to the cathode of the burst keyer (V704-A) through the primary of the bandpass transformer (T702). The secondary of the bandpass transformer supplies chrominance information to the color demodulators.

74. COLOR DEMODULATORS

The bandpass amplifier provides amplified 3.58-mc sideband information to the demodulators (V702 and V703) shown in figure 43. Demodulation is accomplished by a balanced push-pull circuit which provides color difference signals of equal bandwidth (approximately 0.7 mc), thereby eliminating the need for individual channel time-delay equalization. The color subcarrier is reinserted at the cathodes of the demodulator tubes by the 3.58-mc oscillator. Each cathode receives signal voltage in the proper phase, cancelling the 3.58-mc information and providing the correct color difference signal in the plate circuits. The cathodes of the B-Y demodulator are driven by a cw signal differing in phase by 123 degrees from the signal fed to the cathodes of the G-Y demodulator. Transformers T705 and T706 (fig. 44) control the phase of the cw signal. The amplitude of the varying demodulator plate voltage is proportional to the amplitude of the chrominance signal and phased relative to the fixed-phase, cw signal. This synchronous method of detection produces both positive and negative color difference signals. Matrixing the negative B-Y and G-Y signals in the plate circuits of the demodulators produces the R-Y signal. Peaking coils (L702, L705, and L707) in the plate circuit reduce the 3.58-mc information that may appear in the picture. Rf choke coils (L701, L703, and L704) in series with the B-plus supplied to the plates of the demodulators reduce the 3.58-mc harmonic information.

75. MATRIX SECTION

Matrixing is accomplished in the plate circuit of the demodulators for the specific ratios of the color difference signals and in the plate circuit of the second video amplifier for the specific ratios of the luminance signal. Variable resistors R117A, R117B and R136B in the blue and green and red kinescope grid circuits of the matrix section compensate for the different efficiencies of the phosphor dots on the kinescope screen. During a color television transmission, the outputs from the matrix section (the color difference signals) are applied to the grid of the tricolor kinescope and the luminance signal is applied to the cathodes reproducing the original colors of the scene. In black-and-white reception there is no output from the matrix section, and the kinescope grids remain at a fixed level. The variations in the luminance signal at each of the cathodes produce the proportional output necessary to excite each of the phosphors to produce the grey, black, or white required.

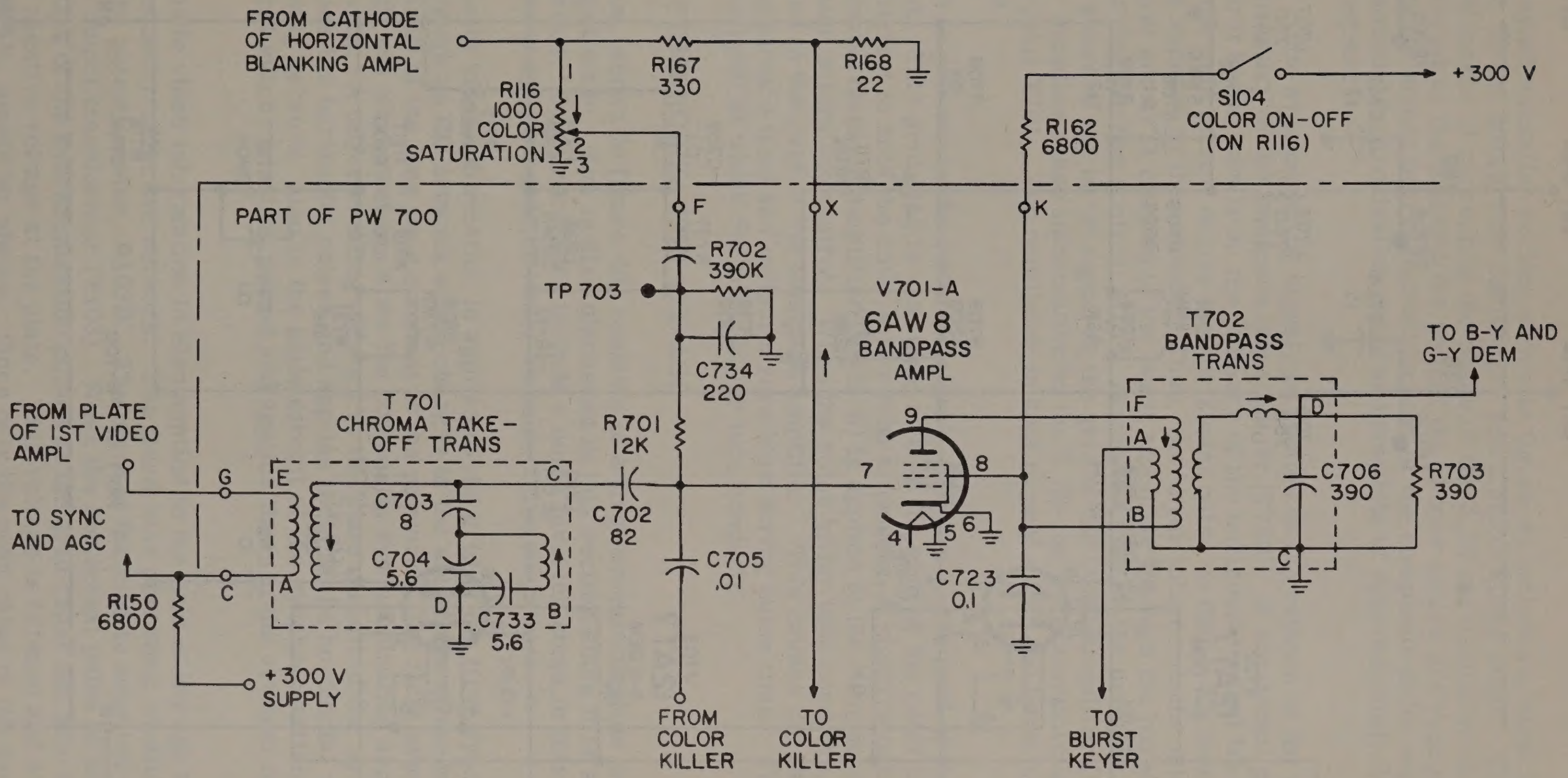

FROM CATHODE OF HORIZONTAL BLANKING AMPL
R116 1000 COLOR SATURATION
1
2
3
R167 330
R168 22
R162 6800
S104 COLOR ON-OFF (ON R116)
+300 V
PART OF PW 700
F
X
K
R702 390K
TP 703
C734 220
V701-A 6AW8 BANDPASS AMPL
T702 BANDPASS TRANS
TO B-Y AND G-Y DEM
FROM PLATE OF 1ST VIDEO AMPL
TO SYNC AND AGC
T 701 CHROMA TAKE-OFF TRANS
R701 12K
G
E
C
C703 8
C704 5.6
C702 82
C705 .01
9
7
8
4
5
6
F
A
B
D
C
C706 390
R703 390
A
D
B
C733 5.6
R150 6800
+300 V SUPPLY
C723 0.1
FROM COLOR KILLER
TO COLOR KILLER
TO BURST KEYER

Figure 42. Bandpass amplifier section.

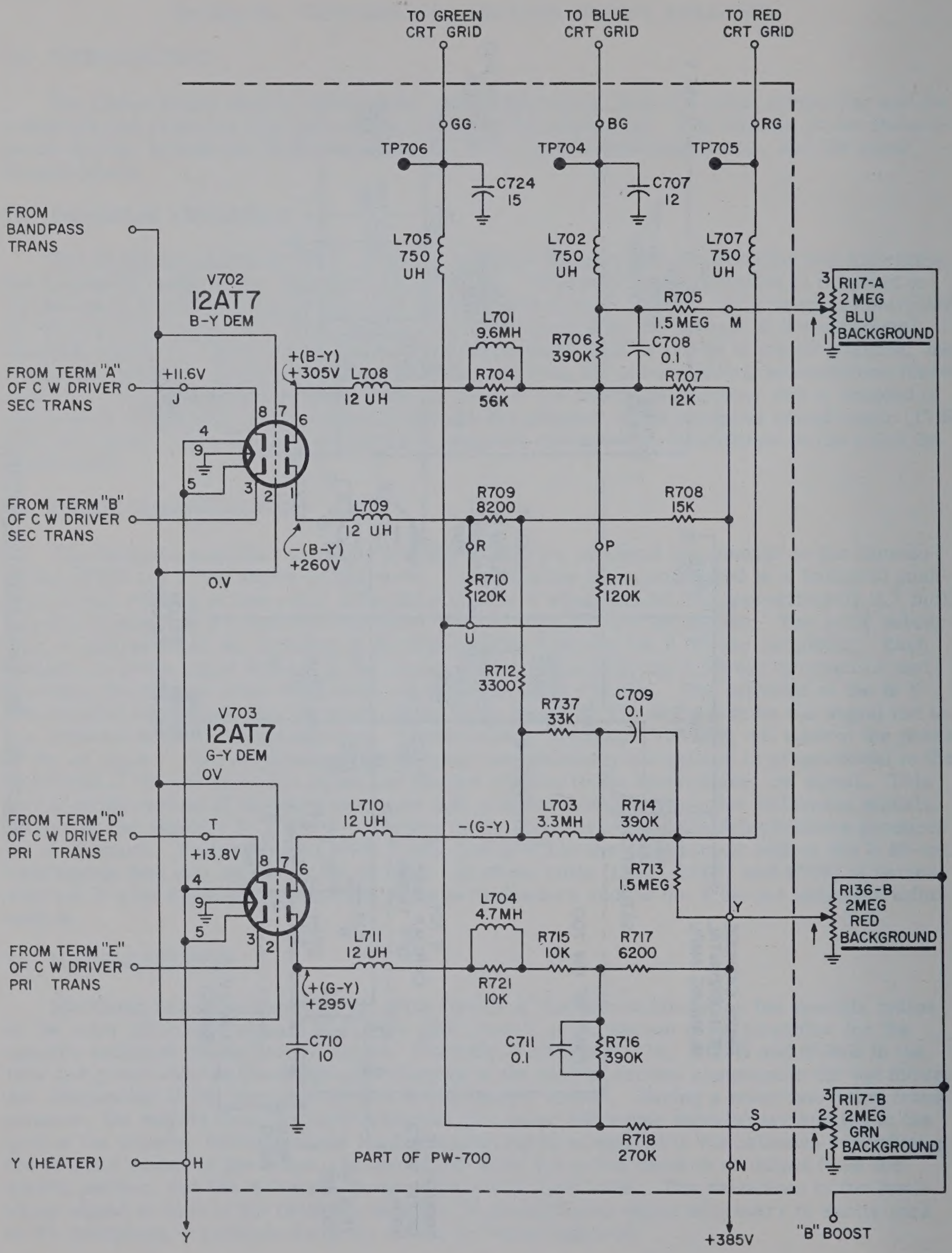

TO GREEN CRT GRID
TO BLUE CRT GRID
TO RED CRT GRID
GG
BG
RG
TP706
TP704
TP705
C724 15
C707 12
FROM BANDPASS TRANS
L705 750 UH
L702 750 UH
L707 750 UH
3
2
1
R117-A 2 MEG BLU BACKGROUND
V702 12AT7 B-Y DEM
R705 1.5 MEG
M
L701 9.6MH
R706 390K
C708 0.1
+(B-Y) +305V
FROM TERM "A" OF C W DRIVER SEC TRANS
+11.6V
J
L708 12 UH
R704 56K
R707 12K
8
7
6
4
9
5
3
2
1
FROM TERM "B" OF C W DRIVER SEC TRANS
L709 12 UH
R709 8200
R708 15K
-(B-Y) +260V
R
P
0.V
R710 120K
R711 120K
U
R712 3300
V703 12AT7 G-Y DEM
R737 33K
C709 0.1
0V
FROM TERM "D" OF C W DRIVER PRI TRANS
T
+13.8V
L710 12 UH
-(G-Y)
L703 3.3MH
R714 390K
R713 1.5MEG
L704 4.7MH
Y
R136-B 2MEG RED BACKGROUND
FROM TERM "E" OF C W DRIVER PRI TRANS
L711 12 UH
R715 10K
R717 6200
R721 10K
+(G-Y) +295V
C710 10
C711 0.1
R716 390K
S
R117-B 2MEG GRN BACKGROUND
R718 270K
Y (HEATER)
H
PART OF PW-700
N
Y
+385V
"B" BOOST

Figure 43. Demodulator section.

76. COLOR SYNCHRONIZING (BURST) SECTION

a. The color synchronization section shown in figure 44 includes a burst keyer stage, a burst amplifier, a 3. 58-mc subcarrier oscillator, and a color-killer stage. This section uses the burst signal as a means of correcting the phase of the 3. 58 mc oscillator to synchronize it with the 3. 58 mc carrier at the transmitter so that the proper colors are reproduced at the proper time. The burst signal is transmitted as part of the composite color signal immediately following each horizontal synchronization pulse and consists of approximately 8 cycles of the color subcarrier frequency.

b. Burst, the color synchronizing signal, is applied to the cathode of the burst keyer tube (V704-A) from the primary of the bandpass transformer (T702). A horizontal pulse is applied to the grid of the burst keyer tube from the primary of the horizontal output transformer (T703). The RC network in the grid circuit delays the horizontal pulse so that it arrives at the grid at the instant the burst appears at the cathode. Thus, the keyer tube conducts only when the burst is present. The burst signal is coupled to the burst amplifier through the burst keyer transformer (T703). Varying the hue control, R164, varies the load on the primary of this transformer causing the phase of the burst signal at the grid of the burst amplifier (V704-B) to vary. The burst amplifier supplies phase information to the 3. 58-mc oscillator through the filter network and control crystal Y701. The oscillator is kept in phase with the burst signals by the injection lock process.

c. When burst is present in the received signal, the bias as the grid of the 3. 58-mc oscillator is increased. This grid bias is also used to bias the grid of the color killer tube (V701-B) and is sufficient to hold the color killer tube at cutoff. A positive pulse from the cathode of the horizontal blanking amplifier (V401-B) is applied to the cathode of the color killer tube at the color saturation control. When the color killer tube conducts, the pulse is amplified and coupled to the grid of the bandpass amplifier. This causes the bandpass amplifier to cut off during picture time and maintain zero bias during pulse time. Threshold control R163 adjusts the level at which the color killer tube conducts.

77. DEFLECTION SYNCHRONIZATION AND AGC

a. This section, shown in figure 45, consists of a first synchronization amplifier and a synchronization output stage. Agc is also discussed in this section since it is so closely related to synchronization. Some receivers include a noise inverter stage in this section to improve the stability of synchronization under impulse noise conditions.

b. The composite video information is applied to the grid of the first synchronization amplifier (V204) through an RC network which charges to the amplitude of the horizontal blanking pedestal as a result of the long time constant of the network. The first synchronization amplifier is normally cut off; however, when the composite synchronization appears at the grid, the tube conducts. A differentiating network in the plate circuit of the synchronization output stage separates the horizontal pulses and applies them to the horizontal oscillator (V601). An integrating network, also in the plate circuit of the synchronization output stage, separates the vertical synchronization pulses and applies them to the vertical oscillator (V501-B).

c. The composite video information is also applied to the grid of the agc amplifier (V204) through a frequency-selective network. The fixed-bias operating condition for the tube is adjusted by the agc potentiometer, R103B. The plate of the tube is supplied with a voltage from the horizontal output transformer (T103). When the horizontal pulse is present at the plate, the positive tips of the synchronization pulses at the grid cause the tube to conduct and produce a rectified negative voltage at the plate. This voltage is filtered and used for a bias source for the rf and i. f. amplifier stages. Since only the peak value of the synchronizing pulses controls the conduction of the agc amplifier, the gain of the rf and i. f. amplifiers depends on the peak value of the signal rather than the average value.

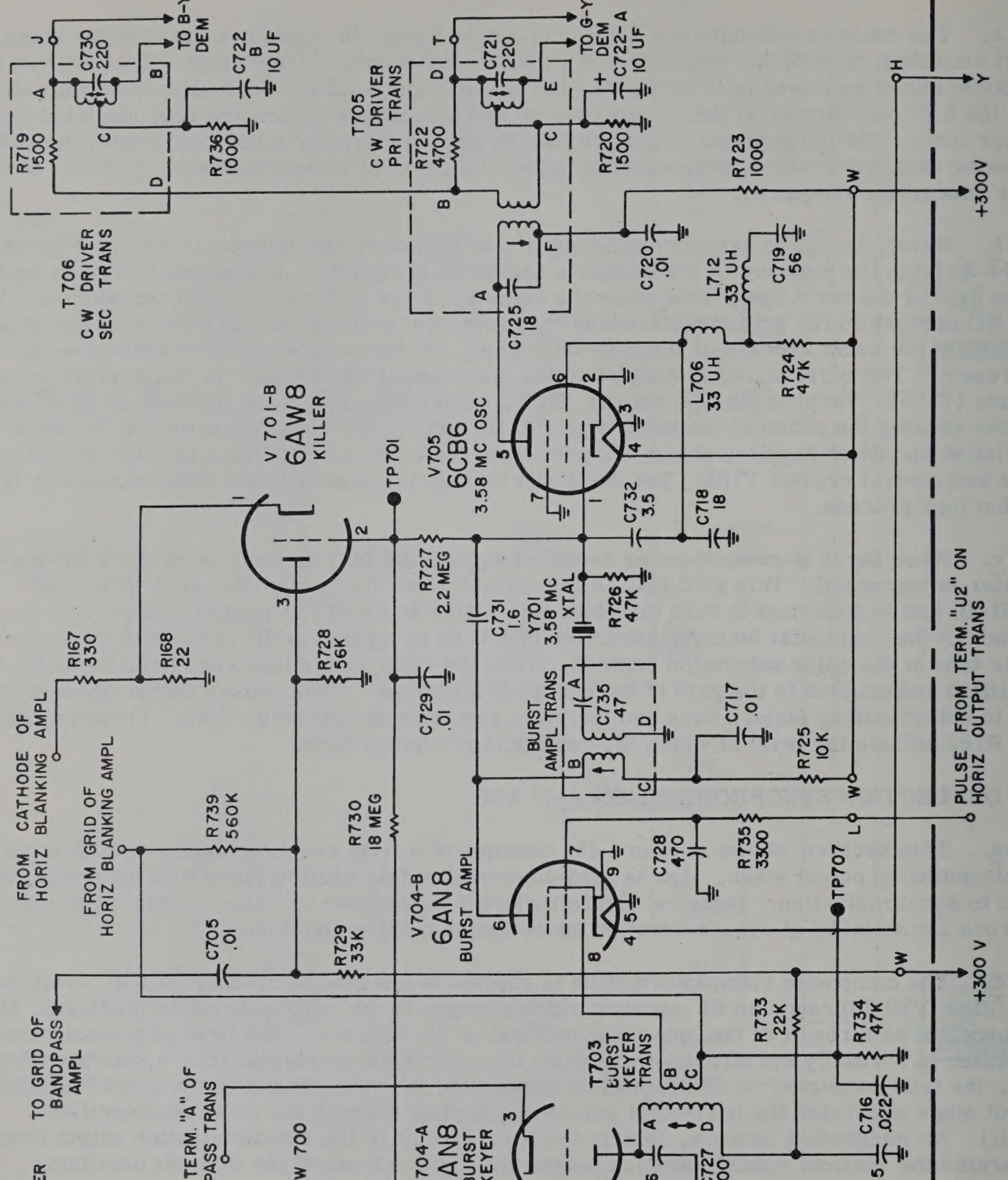

FROM TERM. "U2" ON HORIZ OUTPUT TRANSFORMER
TO GRID OF BANDPASS AMPL
FROM CATHODE OF HORIZ BLANKING AMPL
FROM GRID OF HORIZ BLANKING AMPL
FROM TERM. "A" OF BANDPASS TRANS
PART OF PW 700
+300V
R163 1 MEG KILLER THRESHOLD CONT
V704-A 6AN8 BURST KEYER
TP702
R731 3300
C713 470
C714 0.1
R732 2.2 MEG
C726 120
C727 100
C715 0.1
C716 .022
T703 BURST KEYER TRANS
R733 22K
R734 47K
W103
R164 500 HUE CONT
R166 1000
R180 10
R729 33K
C705 .01
R739 560K
R730 18 MEG
R167 330
R168 22
R728 56K
C729 .01
R727 2.2 MEG
V701-B 6AW8 KILLER
TP701
V704-B 6AN8 BURST AMPL
TP707
C728 470
R735 3300
BURST AMPL TRANS
C735 47
C717 .01
R725 10K
C731 1.6
Y701 3.58 MC XTAL
R726 47K
C732 3.5
C718 18
V705 6CB6 3.58 MC OSC
L706 33 UH
R724 47K
C725 18
L712 33 UH
C719 56
C720 .01
R723 1000
T706 C W DRIVER SEC TRANS
T705 C W DRIVER PRI TRANS
R719 1500
R736 1000
C730 220
C722 B 10 UF
TO B-Y DEM
R722 4700
R720 1500
C721 220
C722-A 10 UF
TO G-Y DEM
PULSE FROM TERM. "U2" ON HORIZ OUTPUT TRANS
+300 V
+300V
Y

Figure 44. Color sync section.

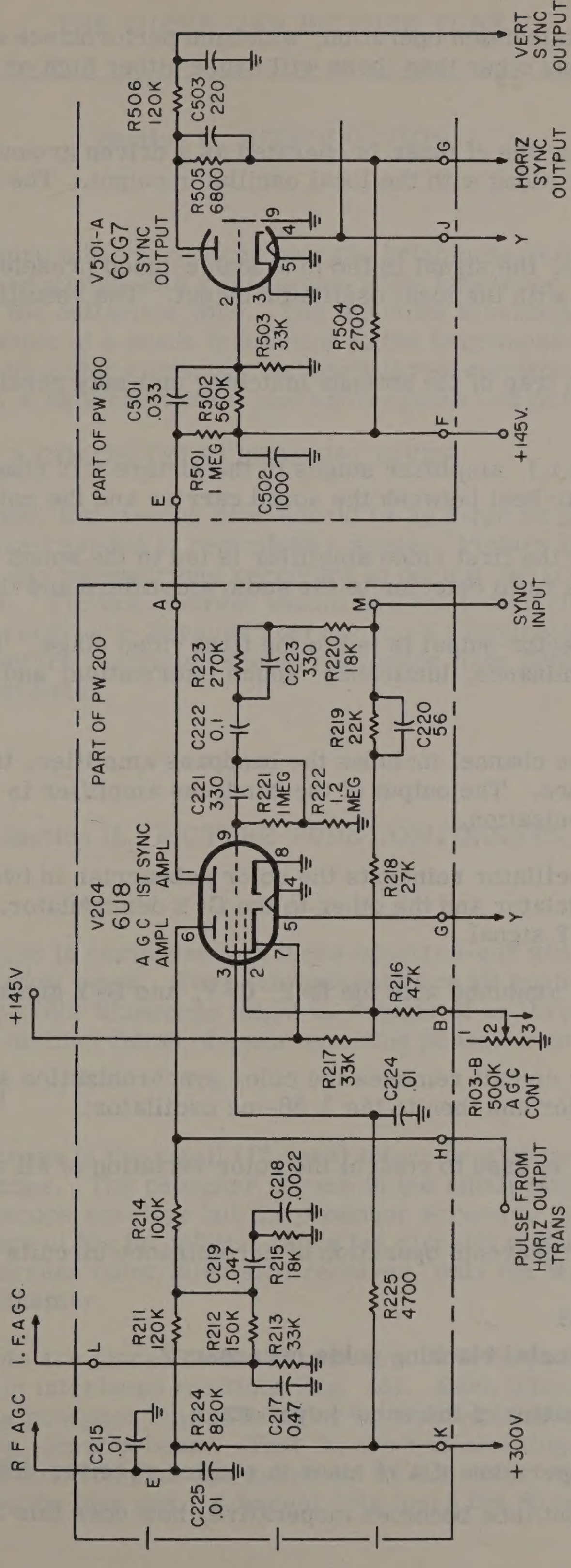

R F AGC
I.F. AGC
E
C215 .01
C225 .01
R224 820K
C217 0.47
K
L
R211 120K
R212 150K
R213 33K
C219 .047
R215 18K
R214 100K
C218 .0022
R225 4700
+300V
H
PULSE FROM HORIZ OUTPUT TRANS
+145V
C224 .01
R217 33K
R216 47K
B
1 2 3
R103-B 500K AGC CONT
V204 6U8 A G C AMPL 1ST SYNC AMPL
3 2 6 7 5 4 8 1 9
R218 27K
G
Y
R221 1 MEG
R222 1.2 MEG
C221 330
C222 0.1
R219 22K
C220 56
R223 270K
C223 330
R220 18K
M
A
SYNC INPUT
PART OF PW 200
PART OF PW 500
E
C501 .033
R501 1 MEG
C502 1000
R502 560K
F
+145V.
R503 33K
R504 2700
V501-A 6CG7 SYNC OUTPUT
2 3 5 4 9
J
Y
R505 6800
G
HORIZ SYNC OUTPUT
R506 120K
C503 220
VERT SYNC OUTPUT

Figure 45. Deflection sync and agc section.

Section IV. SUMMARY AND REVIEW

78. SUMMARY

a. For good color television operation, wideband performance and uniform flat response are necessary. Conditions other than these will cause either high or low saturation and poor color transition.

b. In the vhf ranges, the rf tuner is operated as a driven grounded-grid rf amplifier. Its output is fed to the mixer along with the local oscillator output. The resulting i.f. is sent to the picture i.f. stages.

c. In the uhf ranges, the signal is fed to a double-tuned preselector circuit. This signal is fed to the mixer along with the local oscillator output. The resulting i.f. is sent to the picture i.f. stages.

d. Adjusting the fm trap of the antenna matching unit may result in decreased channel sensitivity.

e. There are three i.f. amplifier stages in the picture i.f. channel. Sound-carrier traps are used to avoid a 920-kc beat between the sound carrier and the color subcarrier.

f. The signal from the first video amplifier is fed to the sound i.f. amplifier. The output is applied through the ratio detector to the audio amplifiers and the output speakers.

g. The picture-detector output is fed to the first video stage. The virst video amplifier provides output for chrominance, luminance, sound information, and deflection synchronization signals.

h. The chrominance channel includes the bandpass amplifier, the demodulator driver, and the color demodulators. The output of the bandpass amplifier is fed to the demodulator driver and color synchronization.

i. The 3.58-mc oscillator reinserts the color subcarrier in two different phases. One is sent to the B-Y demodulator and the other to the G-Y demodulator. These two outputs are combined to form the R-Y signal.

j. The Y signal is combined with the R-Y, G-Y, and B-Y signals in the kinescope to produce color.

k. The burst keyer circuit removes the color synchronization signal. Its output is applied to the burst amplifier and then to the 3.58-mc oscillator.

l. The hue control is used to control the color variation of all three color signals with the burst level.

m. The color killer prevents operation of chrominance circuits in the absence of burst information.

79. REVIEW QUESTIONS

a. Why is the horizontal blanking pulse necessary?

b. Explain the operation of the burst keyer stage.

c. How is the uhf operation of a rf tuner in a color receiver different than vhf operation?

d. If the audio output tube becomes inoperative, how does this affect the rest of the circuits? Why?

e. What are the general functions of the luminance channel?

CHAPTER 6

THE THREE-GUN PICTURE TUBE

Section I. INTRODUCTION

80. GENERAL

The monochrome picture tube reproduces only the brightness variations in a televised scene. The components associated with a black-and-white kinescope include the electron gun, the phosphor screen, and the deflection yoke. The tri-color kinescope must reproduce variations in the hue and saturation of a scene in addition to the brightness variations. The components associated with the tri-color kinescope include a three-electron-gun assembly, a shadow mask, a phosphor screen, a deflection yoke, and convergence and purity magnets.

81. REQUIREMENTS OF A COLOR TELEVISION RECEIVER

In a tri-color kinescope, the viewing area should be as large as practicable in order to reduce the amount of fine detail needed to reproduce a scene. Picture brightness should be comparable to that of present day monochrome receivers to permit the screen to be viewed under average room illumination. Picture contrast should be even better, if possible, than that of present day monochrome receivers, because average room illumination reduces the saturation in color reproduction. Picture resolution should reproduce finer detail than that which is possible in the monochrome system.

Section II. PICTURE TUBE COMPONENTS

82. INTRODUCTION

The tri-color kinescope is composed of a three-electron-gun assembly, a phosphor dot viewing screen, and a shadow mask. These components are all contained within the tube envelope. Actually, the tri-color kinescope might be thought of as three tubes in one since there are three guns and three distinct fields of color-emitting phosphor on the faceplate.

83. PHOSPHOR SCREEN

a. The phosphor screen in the small (15-inch) tri-color kinescope differs from the large (21-inch) tri-color kinescope. The phosphor screen in the small kinescope is printed on a plate mounted in the kinescope envelope but the phosphor screen in the large kinescope is printed directly on the back of the faceplate. Since the circuits discussed in previous chapters deal only with the large-screen color television receiver, only the large tri-color kinescope will be discussed in this chapter.

b. The phosphor dots are placed on the screen in a definite pattern in which groups of three (a trio) are placed in interlaced positions (fig. 46). Each trio consists of a blue-, a green- and a red-emitting phosphor dot. The color is emitted from each dot when it is activated by its corresponding electron beam. That is, the red-emitting phosphor dot is activated by the beam from the red electron gun, the green dot by the beam from the green gun, and the blue dot by the beam from the blue gun. Adjacent dots touch but do not overlap.

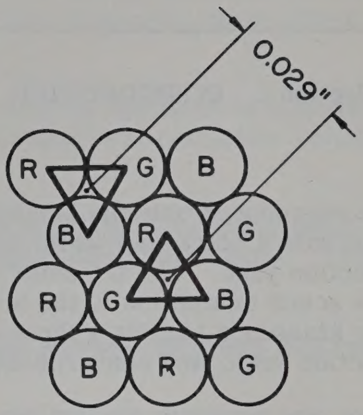


Figure 46. Phosphor dot trios.

c. In the large tri-color kinescope, the spacing between the centers of adjacent dot trios is 0.029 inch. The size of the phosphor dots has been kept small to keep the colored dot pattern invisible at normal viewing distances. Approximately one million phosphor dots are used (357,000 trios). The faceplate is rounded to help equalize the length of beam travel to different parts of the screen and simplify the dynamic convergence and focusing requirements.

84. SHADOW MASK

a. A thin metal plate, called the shadow mask, is located between the phosphor dot screen and the electron gun assembly (fig. 47). It has approximately the same curvature as the phosphor dot screen. There are 357,000 holes 0.009 inch in diameter in the shadow mask (one hole for each phosphor dot trio), and these holes are spaced 0.023 inch between centers. The edges of all the holes are beveled by an etching process so that an equal hole area is presented to the beams for any angle of beam deflection. The shadow mask provides color separation by shadowing two of the three arrays of dots from two of the three electron beams while exposing the proper array to bombardment by each beam. The shadow mask is also used in the manufacturing process to form the pattern employed in depositing the phosphors on the phosphor dot screen. This ensures that dot trios will be in the correct position behind any hole in the shadow mask for any angle of deflection.

b. A change in alignment of the shadow mask with respect to the phosphor dot screen due to heat expansion can result in color impurity. To maintain alignment, the expansion of the shadow mask in the picture tube is controlled as the mask heats. A specially designed mounting ring compensates for mask expansion due to temperature changes by permitting the apertures to move in the direction of the beam travel and thus minimizes any change in the alignment of dot trios and apertures.

85. ELECTRON GUN STRUCTURE

a. The three-electron-gun assembly, shown in figure 48, is manufactured as one unit and mounted in the neck of the picture tube. The three electron guns are approximately parallel to each other and 120 degrees apart. Each of the three guns is tilted slightly toward the central axis of the tube so that the three beams converge at the shadow mask. The tilt of the guns greatly reduces the amount of static convergence correction required. In order to obtain the shortest possible overall picture-tube length without greatly increasing the angle of deflection,

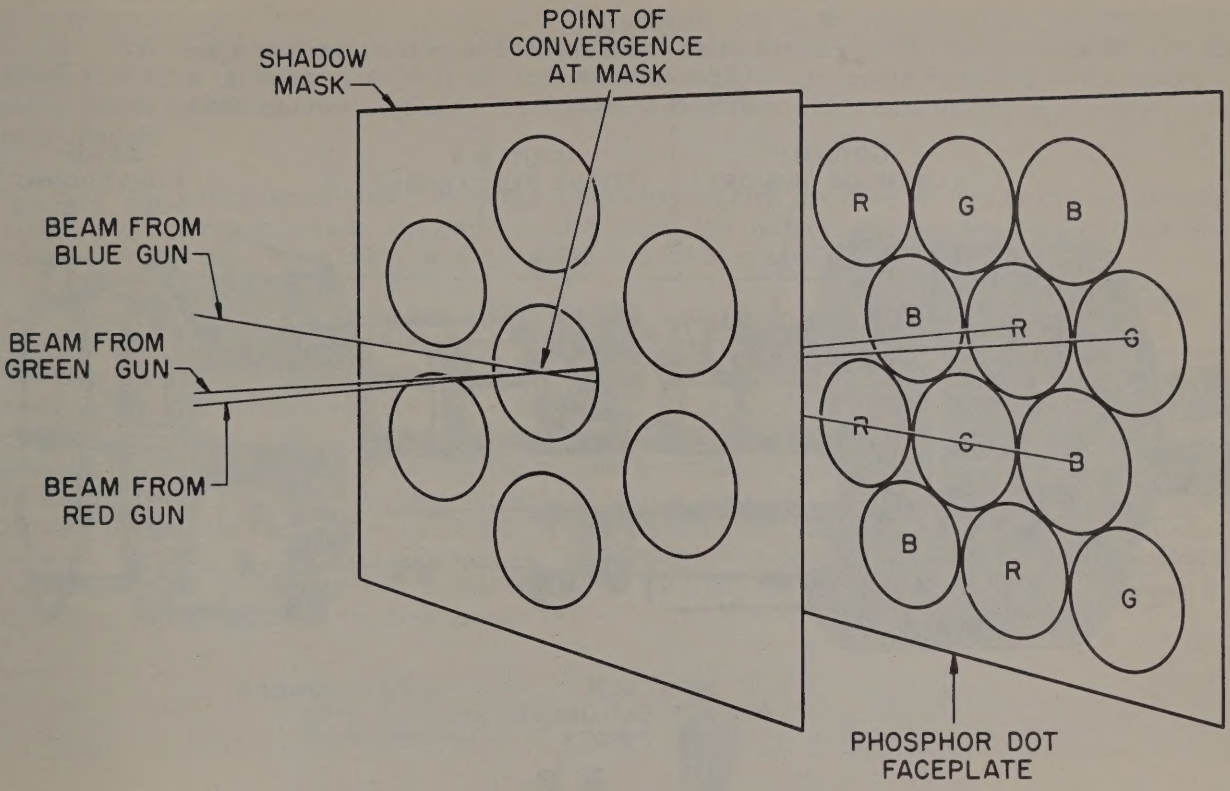


Figure 47. Shadow mask and convergence relationship.

the length of the electron-gun assembly was made as short as possible.

b. Each of the electron guns is flanked by a pair of internal magnetic pole pieces. These direct the magnetic convergence fields to the area directly in front of the guns, thereby minimizing interaction between guns. An additional internal pole piece, known as the blue-positioning pole piece, is supplied for the blue gun.

c. There are five grids on each electron gun. Grid number 1 is the control grid; grid number 2 is the accelerating anode, commonly called the kinescope screen grid. Grid number 3, the focus electrode, provides a focus adjustment common to all electron beams so that each beam comes to focus on the phosphor dot screen. Grids 4 and 5 are called the ultor and collector grids. They are operated at the aquadag voltage and are common to all three guns. Their purpose is to bend the three electron beams so that they converge or cross exactly at the hole in the shadow mask.

86. OPERATION OF THE TRI-COLOR KINESCOPE

The intensity and rate of acceleration of the electrons emitted from the cathode of each gun are determined by the control and acceleration grids, respectively. As the beams pass these grids, they are aligned with each other and parallel to the central axis of the kinescope. This alignment is maintained by a purity magnet around the outside of the kinescope. The beams are focused as they pass the third grid. The focused beams then pass through a dynamic convergence field causing them to converge at the shadow mask and excite the appropriate phosphor dots regardless of the angle of deflection. As the angle of deflection increases,

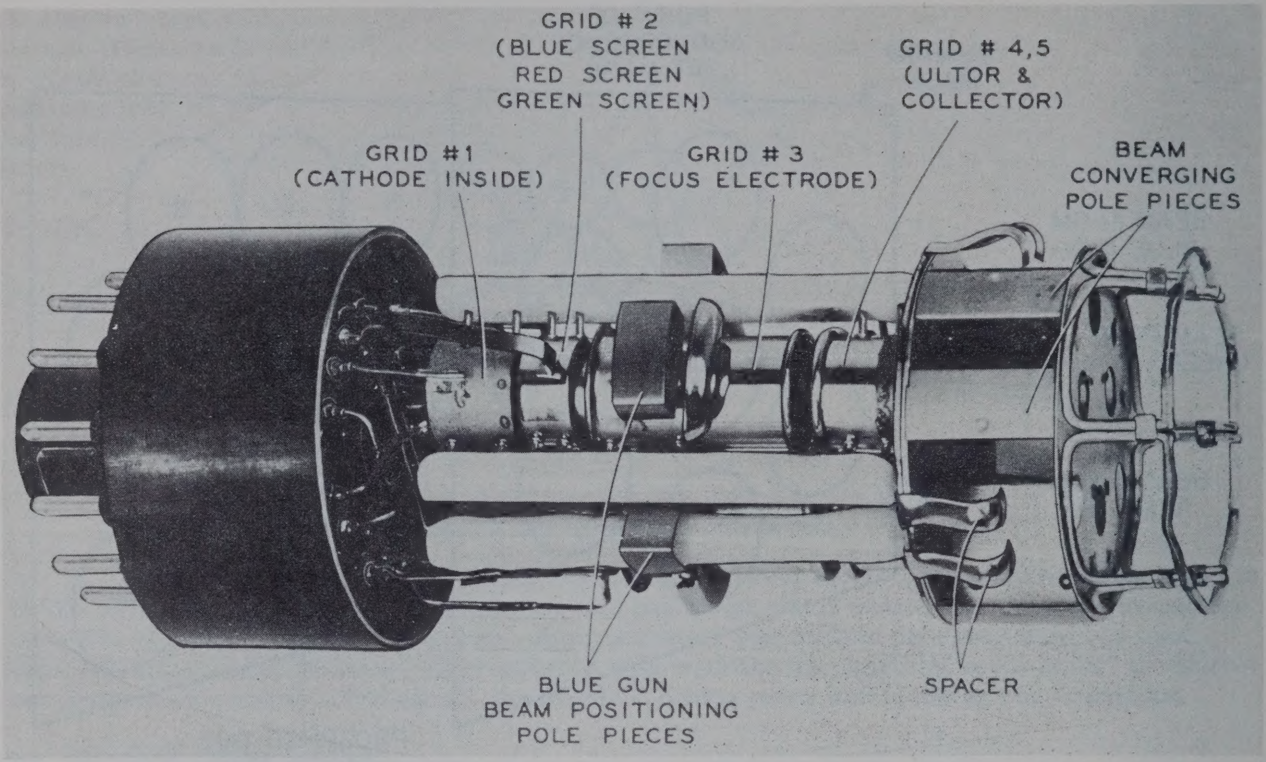

GRID # 2
(BLUE SCREEN
RED SCREEN
GREEN SCREEN)
GRID # 4,5
(ULTOR &
COLLECTOR)
GRID #1
(CATHODE INSIDE)
GRID # 3
(FOCUS ELECTRODE)
BEAM
CONVERGING
POLE PIECES
BLUE GUN
BEAM POSITIONING
POLE PIECES
SPACER

Figure 48. Tricolor kinescope electron guns.

the strength of the dynamic convergence field decreases. The dynamic convergence field changes the distance at which the beams converge as the distance between the guns and the shadow mask increases or decreases.

Section III. ACCESSORY COMPONENTS

87. GENERAL

a. Various components are used with the tri-color kinescope to reproduce scenes in their original colors. This section will discuss the accessory components required to maintain color purity and beam convergence. Purity and convergence circuits will be discussed in the next chapter.

b. The components installed on the kinescope include the blue lateral beam-positioning magnet, the purity magnets, the convergence yoke, the deflection yoke, the high-voltage insulator (referred to as a boot), and the color equalizer magnets.

88. THE BLUE LATERAL BEAM-POSITIONING MAGNET

The blue lateral beam-positioning magnet shown in figures 49 and 50 controls the lateral movement of the beam from the blue electron gun. Lateral control of the blue beam facilitates convergence adjustments. Two types of lateral control are commonly found in a color television receiver. One type positions the magnet over the blue gun pole piece and operates electromagnetically from a dc voltage supplied from the horizontal output tube. A separate control adjusts the blue beam along a horizontal plane. The other type positions a permanent magnet between the blue and red gun pole pieces. This magnet is physically rotated and its magnetic field affects all three beams. As the magnet is rotated, the red and green beams move in a direction opposite that of the blue beam.

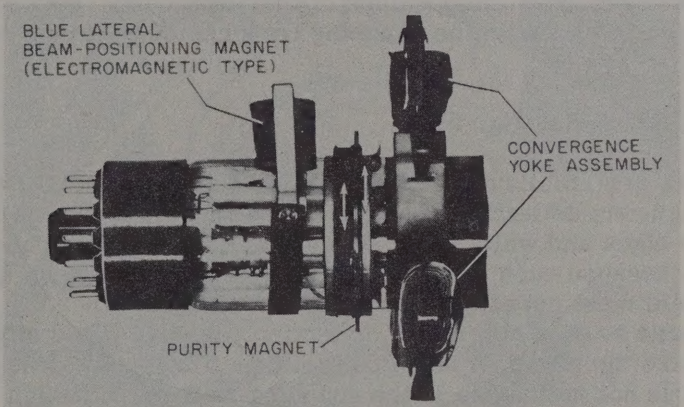


Figure 49. Blue lateral beam positioning magnets.

89. THE PURITY MAGNETS

The purity magnets are located at the base of the tube (fig. 50) and usually consist of two ring-type magnets. Purity is achieved when the beam from each electron gun passes through the shadow mask and excites the centers of its respective phosphor dots on the kinescope screen. Rotating one or both of the magnets rotates the field produced by the magnet, aligning the three electron beams. Thus, each beam strikes only its corresponding phosphor dots. For example, with only the green gun in operation, a uniform green raster should be observed. Positioning the deflection yoke and adjusting the color equalizer magnets also aid in obtaining purity.

90. THE CONVERGENCE YOKE (fig. 49 and 51)

a. The three electron beams must converge at every aperture in the shadow mask. The beams converge as a result of the mechanical alignment of the electron guns and the electromagnetic positioning of the beams with respect to the kinescope axis. Static convergence, as this is called, is maintained by controlling the intensity of the magnetic field produced by an electromagnet placed above the respective convergence pole-pieces in the electron guns. The controlling dc voltage is supplied by the horizontal output tube.

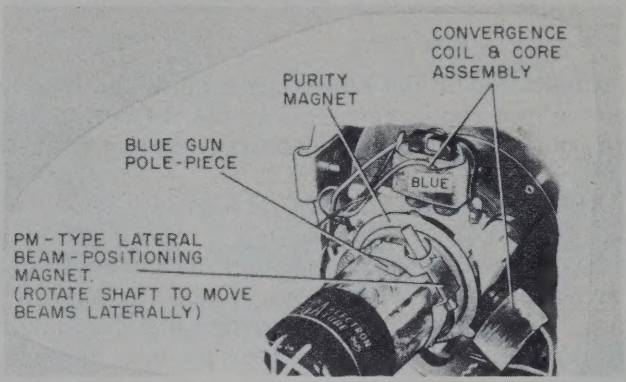


Figure 50. Convergence yoke and purity magnets.

b. Currents supplied by the horizontal and vertical sweep output stages are applied to the electromagnets positioned above the openings of the beam converging pole-pieces, thereby synchronizing the magnetic fields with the scanning frequencies. This produces dynamic convergence.

91. THE DEFLECTION YOKE (fig. 51)

Because the yoke in a color receiver must produce symmetrical and uniform magnetic fields for the simultaneous deflection of all three beams, the design of the yoke is more complex than it is in the black and white tube. This simultaneous deflection introduces certain structural problems because each beam is at a different position when passing through the yoke, and the deflecting field must not affect one beam more than another. In a monochrome rereceiver, the end turns in each coil of the deflection yoke are lifted slightly away from the neck of the tube to minimize the effect on beam deflection. These end turns affect the electron beam, but the effect is not noticeable in the scanning raster. Although deflection in a color receiver would be similarly impaired by the effect of the end turns of the deflection yoke, convergence would be more seriously affected. Therefore, the end turns of the color receiver yoke must be lifted well away from the neck of the tube to reduce their effect on deflection and convergence.

92. THE HIGH-VOLTAGE INSULATOR (BOOT)

The high-voltage insulator, also called the boot (fig. 52), serves five purposes. It is a partial mechanical mount for the kinescope, a mechanical mount for the deflection yoke, a horizontal frequency radiation shield, a high-voltage capacitor forming a 2200 uuf capacitance between the metal surface and the external conductive coating which is grounded, and a high-voltage protective shield.

93. THE COLOR EQUALIZER MAGNETS (fig. 53)

To compensate for external magnetic fields, six circular permanent magnets are mounted about the rim of the boot. Each magnet can be rotated to move toward or away from the face of the kinescope to provide a localized magnetic field of variable intensity. This field neutralizes stray magnetic fields near the edges of the kinescope which may deflect electron beams and cause color impurity around the edge of the picture.

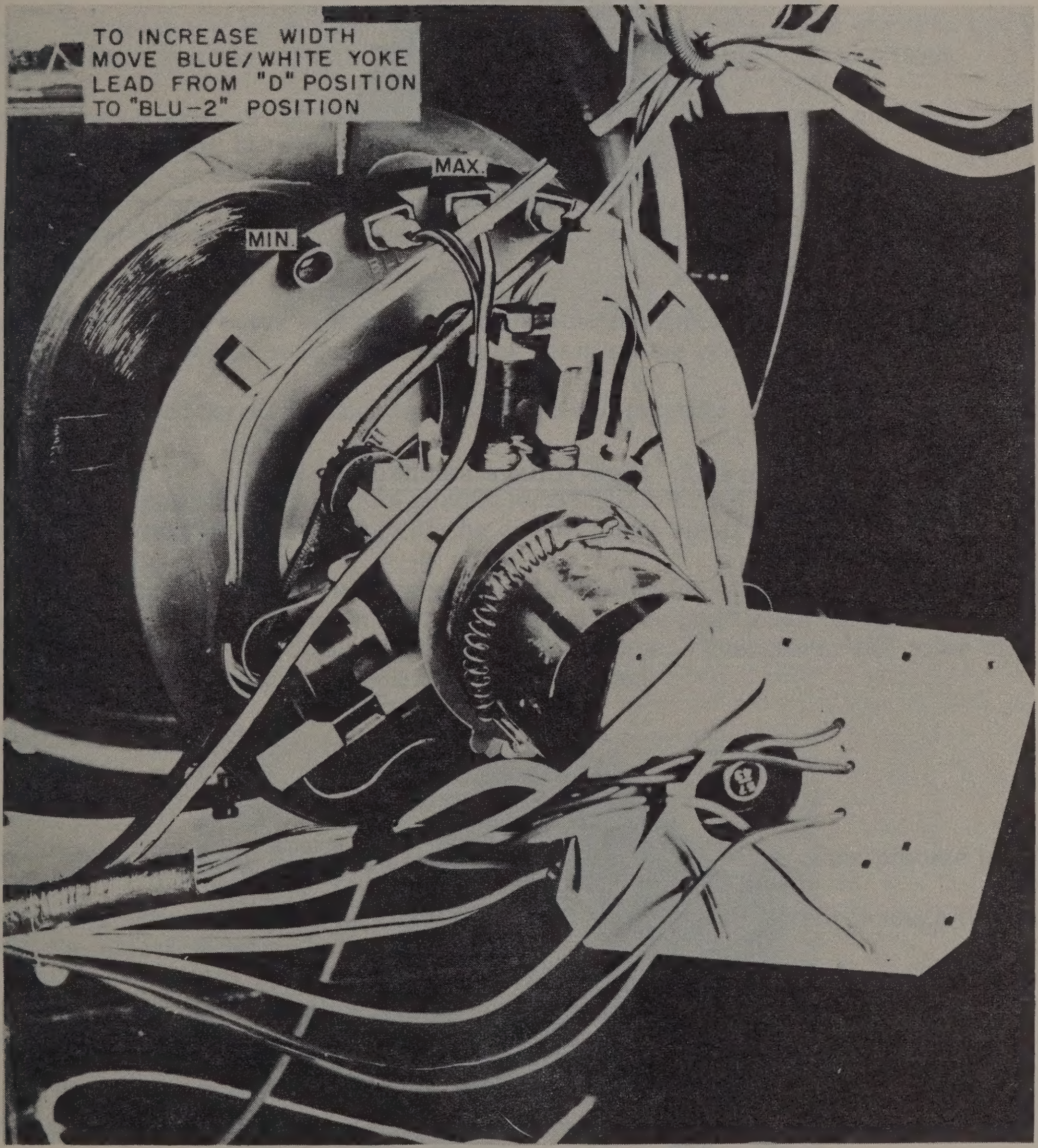

TO INCREASE WIDTH MOVE BLUE/WHITE YOKE LEAD FROM "D" POSITION TO "BLU-2" POSITION
MAX.
MIN.

Figure 51. Deflection yoke.

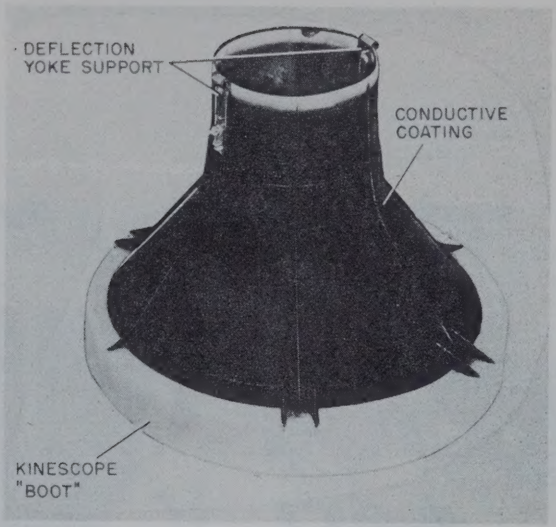

DEFLECTION YOKE SUPPORT
CONDUCTIVE COATING
KINESCOPE "BOOT"

Figure 52. High-voltage insulator.

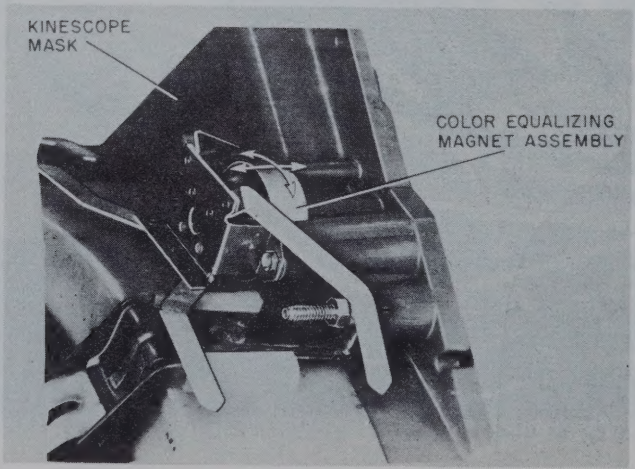

KINESCOPE MASK
COLOR EQUALIZING MAGNET ASSEMBLY

Figure 53. Color equalizing magnets.

Section IV. SUMMARY AND REVIEW

94. SUMMARY

a. The color picture tube must reproduce a scene with its original brightness and color variations.

b. Any color reproducer uses the primary colors red, green, and blue. It must have a large picture area, a high degree of picture brightness, high contrast range, and fine picture detail.

c. The tri-color kinescope contains a red, a blue, and a green electron gun within one envelope. Each gun has its own video signal and its own color-emitting field.

d. The cathodes of the electron guns in the tri-color kinescope emit beams of electrons which converge at the shadow mask and scan the phosphor dot screen.

e. The electron guns are mounted 120 degrees apart in the picture tube neck and tilted toward the central axis. There are four internal pole pieces and grids on each gun in the electron gun assembly.

f. The shadow mask is mounted between the phosphor dot screen and the electron gun assembly. It is used to control the electron beam on the phosphor dot screen.

g. The small phosphor dots are printed close together on the back of the rounded faceplate.

h. Beam positioning magnets permit individual convergence adjustments for each of the three beams by varying the voltage on the convergence electrode.

i. The yoke produces the proper magnetic fields for the simultaneous and equal deflection of all three beams. The end turns of each coil are positioned further away from the neck of the color tube than they are on the monochrome tube. Therefore, the color tube yoke is much larger than that used for monochrome operation.

95. REVIEW QUESTIONS

a. What is the purpose of the shadow mask?

b. Why is the position of the yoke critical in a three-beam color picture tube?

c. What effect does the magnetic field produced by the current through the purity coil have on the electron beams?

d. In a tube which employs magnetic convergence, how are the electron guns positioned to aid in obtaining static convergence of the beams at the shadow mask?

e. What auxiliary components can be adjusted to obtain optimum color purity in a tube employing the magnetic principle?

CHAPTER 7

COLOR TELEVISION DEFLECTION AND CONVERGENCE CIRCUITS

Section I. DEFLECTION AND CONVERGENCE PRINCIPLES

96. INTRODUCTION

This chapter discusses the circuits in a color television receiver that are associated with the deflection and convergence of the electron beams in the tri-color kinescope. These circuits include the high- and low-voltage supplies and the vertical- and horizontal-oscillator output circuits. Before proceeding with the study of the individual circuits, the principles of deflection and convergence will be discussed.

97. BEAM CONTROL

a. In the monochrome picture tube, beam control involves only two considerations: deflection and focusing. The color picture tube has two additional requirements for controlling the three beams used. First, the beams must be properly aligned to strike only their respective color-phosphor dots; second, the beams must converge at the holes in the shadow mask.

b. The electrons emitted from the cathode of each gun are intensified and accelerated by the control grid and acceleration anode respectively. The three beams are brought into focus on the tri-color kinescope screen by the third trio of grids which are electrically connected to provide the same potential at each grid. Before the three beams pass through the convergence field, they must be parallel to the central axis of the tube and equidistant from each other. This alignment is maintained by the purity magnet mounted outside the neck of the tube.

98. CONVERGENCE FIELD

a. After the beams pass the focusing anode, they enter a convergence field which causes them to cross at the aperture of the shadow mask and strike the phosphor screen. A static convergence field may be obtained by using the potential difference between grid number 4 and the coating on the inside of the tube or by using electromagnets mounted around the neck of the tube. If the beams were undeflected or in a static state this method of obtaining convergence would be adequate. However, the beams are constantly being deflected across the face of the tube.

b. As the deflection angle shown in figure 54 is increased, the beams converge at an increased distance behind the aperture mask. To correct this condition and bring the point of convergence to the appropriate aperture in the shadow mask, dynamic convergence is employed. Dynamic convergence can be obtained by using the current from the horizontal and vertical deflection circuits, since the horizontal and vertical scanning rates determine the rate of change in the deflection angles of the beams. As the deflection angle increases, the convergence force decreases to allow the beams to converge at a point farther from the deflection plane. Thus, varying the strength of the convergence field at the horizontal and vertical scanning rates, dynamic convergence is obtained.

99. DYNAMIC FOCUSING

Focusing is achieved when the electrons within an electron beam converge at the phosphor screen as the beam is deflected across the face of the kinescope. This is accomplished by applying a voltage which varies with the scanning rates to the focus electrode. Dynamic focusing is achieved when the three electron beams are focused on the appropriate phosphor dots after the beams converge at the shadow mask.

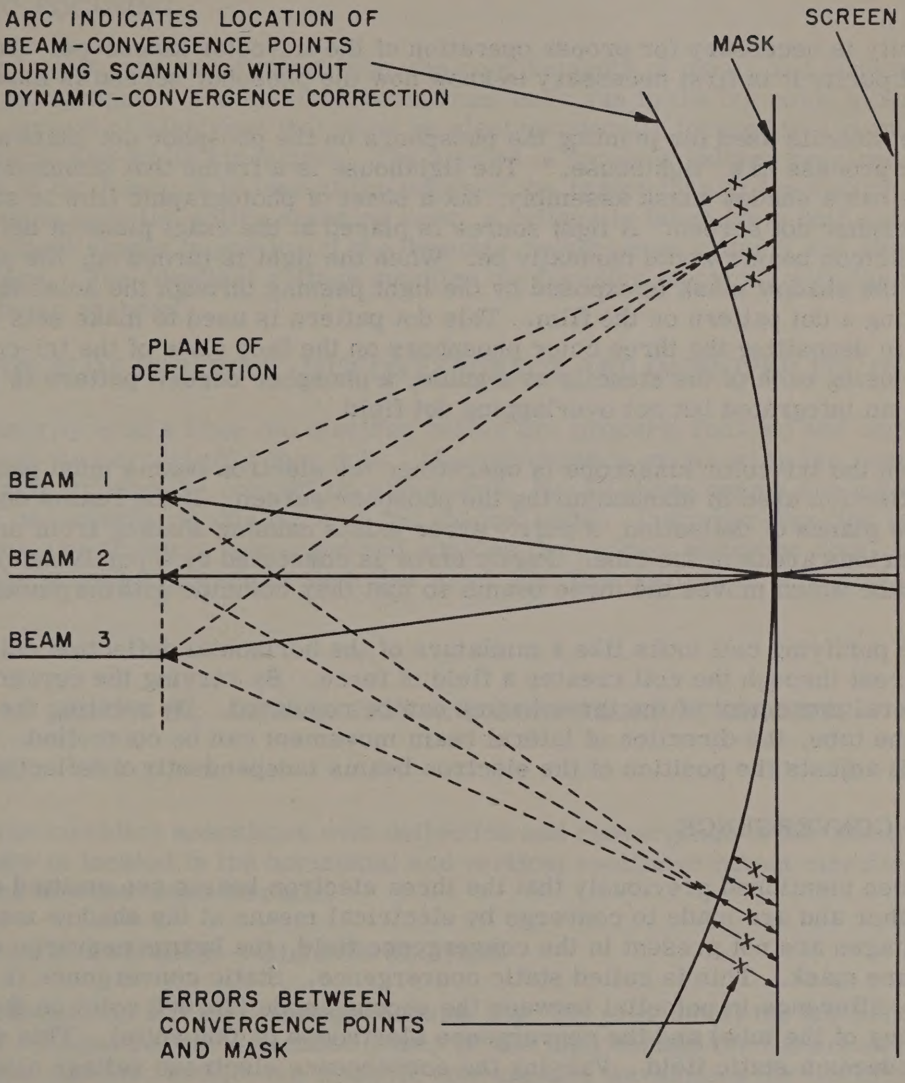

ARC INDICATES LOCATION OF BEAM-CONVERGENCE POINTS DURING SCANNING WITHOUT DYNAMIC-CONVERGENCE CORRECTION
SCREEN
MASK
PLANE OF DEFLECTION
BEAM 1
BEAM 2
BEAM 3
ERRORS BETWEEN CONVERGENCE POINTS AND MASK

Figure 54. Effect of deflection without dynamic convergence.

Section II. TRI-COLOR KINESCOPE CHARACTERISTICS

100. GENERAL

Optimum performance can be achieved with the tri-color kinescope through the use of external magnetic adjusting devices and adjustable internal electrostatic fields. The methods by which optimum performance is obtained are discussed in the following paragraphs.

101. PURITY

a. Purity is necessary for proper operation of the tri-color kinescope. To understand the nature of purity it is first necessary to know how the phosphor screen is made.

b. The stencils used for printing the phosphors on the phosphor dot plate are made by a photographic process in a "lighthouse." The lighthouse is a frame that simulates an operating kinescope; it has a shadow mask assembly, but a sheet of photographic film is substituted for the usual phosphor dot screen. A light source is placed at the exact plane of deflection where one of the electron beams would normally be. When the light is turned on, the photographic plate behind the shadow mask is exposed by the light passing through the holes in the shadow mask, creating a dot pattern on the film. This dot pattern is used to make sets of three stencils for use in depositing the three color phosphors on the face plate of the tri-color kinescope. By carefully using each of the stencils as a guide, a phosphor deposit pattern is produced which forms an integrated but not overlapping dot field.

c. When the tri-color kinescope is operating, the electron beams must pass through the planes of deflection used in manufacturing the phosphor screen. If the beams do not pass through these planes of deflection, a purity error exists causing shading from one color to another in various areas of the tube. Purity error is corrected by a purifying coil around the neck of the tube which moves the three beams so that they coincide with the planes of deflection.

d. The purifying coil looks like a miniature of the horizontal deflection coils of the yoke. A direct current through the coil creates a field of force. By varying the current through the coil, the lateral movement of the three beams can be regulated. By rotating the coil around the neck of the tube, the direction of lateral beam movement can be controlled. Thus, the purifying coil adjusts the position of the electron beams independently of deflection yoke current.

102. STATIC CONVERGENCE

It has been mentioned previously that the three electron beams are emitted equidistant from each other and are made to converge by electrical means at the shadow mask. When scanning voltages are not present in the convergence field, the beams converge at the center of the aperture mask. This is called static convergence. Static convergence is the direct result of the difference in potential between the second anode (20, 000 volts on the inner conductive coating of the tube) and the convergence electrodes (9, 000 volts). This difference in potential produces a static field. Varying the convergence electrode voltage alters this static field, converging the three beams at the shadow mask in the center area of the kinescope.

103. DYNAMIC CONVERGENCE

In the process of deflection, an electron beam will describe an arc within the kinescope. Since the shadow mask in the tri-color kinescope is almost a flat surface, a beam length that is adequate for the center of the shadow mask will not be adequate for the edges. As the deflection angle is increased, the point of convergence pulls away from the shadow mask causing the beams to spread at the edges of the phosphor dot screen. In order for the three beams to converge at every aperture in the shadow mask, the voltage on the convergence anode must change with beam deflection. Keep in mind that the necessary modulating voltage must vary the point of convergence both horizontally and vertically in step with the raster scanning rates.

The logical place to find such a voltage is at the horizontal and vertical deflection output stages, since they develop voltages that vary at the prescribed rates. Waveforms of the required parabolic shape are found at the plate of the horizontal output stage and at the cathode of the vertical output tube. These waveforms from the two stages are combined to form a new waveshape. The new waveshape, when applied with the proper amplitude and phase relationships to the converging electrode, maintains beam convergence at the shadow mask through all angles of beam deflection.

104. DYNAMIC FOCUSING

Focusing is separate and distinct from the requirements of purity and convergence covered in preceding paragraphs. The electron beam from each gun in the tri-color kinescope tube consists of a stream of electrons that must be electrostatically focused to a point on the screen, just as in a black-and-white kinescope. The amount of focusing voltage required varies with the deflection of the beam; it is less at the edges of the raster than at the center. To ensure accurate focusing over the entire scanning area, a voltage is taken from both the horizontal and vertical output stages (a portion of the dynamic convergence voltage) and added to the dc vocusing voltage. The resultant voltage supplies the focusing electrode with the proper voltage for the area being scanned.

105. COMPARISON OF IMPURITY, MISCONVERGENCE AND IMPROPER FOCUS

Color impurity exists when the electron beams are properly focused and converged, but are not striking the correct phosphor dots. Misconvergence exists when the beams are properly focused and striking the correct phosphor dots, but all three beams are not entering a common hole or crossing at this point on the shadow mask. Improper focusing exists when the electron beams are properly converged and striking the correct phosphor dots, but the beam diameter at the phosphor screen is such that more than one dot trio is activated by one trio of beams.

Section III. DEFLECTION AND CONVERGENCE CIRCUITS

106. GENERAL

Most of the circuitry associated with deflection and convergence of the electron beams in the picture tube is located in the horizontal and vertical oscillator output circuits. The following paragraphs discuss these circuits.

107. DEFLECTION AND HIGH-VOLTAGE SECTION

a. The deflection and high-voltage circuits (fig. 36) provide (1) the horizontal and vertical deflection voltages for the deflection yoke, (2) the high voltage for the acceleration, focus, and convergence anodes, and (3) the dynamic convergence waveforms for the kinescope convergence anode. All of these functions are associated with high voltage and the horizontal and vertical oscillators.

b. The horizontal and vertical oscillators (V601 and V501-B) maintain horizontal and vertical synchronization and drive the horizontal and vertical output circuits. A fly-back transformer is used in the horizontal output circuit to develop horizontal sweep and high voltages. Synchronization signals for horizontal and vertical deflection control are obtained from the synchronization stages and are fed to the grid circuits of the horizontal and vertical oscillators, respectively.

108. VERTICAL DEFLECTION SECTION

The vertical deflection section consists of an oscillator, an output tube, and an output transformer. The vertical oscillator plate circuit contains the height control (R144-B) and is supplied from the B-boost voltage source so that picture height will not vary with changes in brightness. Linearity and vertical hold controls (R108-A and R144-A) are also found in this section. The horizontal output transformer (T104) supplies vertical convergence voltages to the convergence circuits and vertical sawtooth currents to the coils in the vertical deflection yoke through a vertical isolation winding in the horizontal output transformer (T103). Thus, the vertical yoke operates at a horizontal pulse potential. Vertical centering is accomplished by adjusting the vertical centering control (R134) in the bridge network composed of the bifilar winding in the vertical output transformer, the isolation winding in the horizontal output transformer, and the vertical deflection coils. When the bridge circuit is balanced, the raster is properly centered.

109. VERTICAL CONVERGENCE

a. A voltage obtained from the cathode of the vertical output tube (V502) is fed to the vertical amplitude controls (R141-A, R142-A, and R143-A) which regulate the amount of vertical parabolic voltage applied to the convergence coils.

b. Sawtooth voltages, obtained from secondary windings of the vertical output transformer, are applied across the variable vertical-tilt controls (R141-B, R142-B, and R143-B). Since these voltages are of similar shape but of opposite polarity, zero voltage with respect to ground is obtained near the center of the controls. By applying these voltages to the convergence coils, the waveshapes of the parabolic voltages can be varied.

110. HEIGHT AND VERTICAL LINEARITY CONTROLS

a. By varying R114B in the vertical oscillator output circuit, the amplitude of the sawtooth wave is varied. The peak-to-peak amplitude of the vertical sawtooth wave determines the amount of vertical deflection on the kinescope screen.

b. Varying R108A in the grid circuit of the vertical output tube varies the control-grid bias of the vertical oscillator. Varying the control-grid bias shifts the operating point of the tube and allows more linear operation.

111. HORIZONTAL DEFLECTION AND HIGH VOLTAGE

a. The horizontal deflection and high-voltage section of the receiver is composed of an oscillator and control circuit, a sweep output stage, an output transformer, and high-voltage and focus-voltage sources. The horizontal oscillator and sweep control stage supply grid-drive voltage to the horizontal sweep output tube. The high-voltage portion of the receiver uses a high-voltage rectifier which supplies the 19, 500 volts required at the kinescope ultor anode.

b. Since changes in picture content (dark scenes to light scenes) causes the high voltage to vary, the receiver must have some means for keeping the high voltage constant. This is accomplished by the high-voltage regulator circuit which is in parallel with the high-voltage output. Assume that the high voltage is at 19, 500 volts and that there is a light scene on the screen. This requires high beam current since all three beams are required to illuminate the light areas. If the scene suddenly shifts from light to dark, less beam current is required. When the drop in beam current occurs, the high voltage would rise if the voltage regulator was not used. At 19, 500 volts a given current flows through the voltage regulator (V105). When the high voltage tends to rise, the B-boost voltage from the horizontal output transformer (which also tends to rise) is applied to the grid of the regulator, permitting the tube to draw more current and thus lowering the voltage. Should the high voltage tend to decrease, the B-boost voltage would decrease and the current through the regulator would decrease, permitting the voltage to rise. Regulation occurs when the drop in high voltage lowers the current through the regulator enough to offset the increase in kinescope beam current.

c. Voltage for the kinescope focus anode is obtained from taps on the high voltage transformer. Resistor R129 is inserted across the tapped portion of the transformer, and its center arm provides control for the voltage supplied to the focus rectifier.

112. HORIZONTAL CONVERGENCE

A convergence system using parabolic waves for horizontal convergence is shown in figure 36. The voltage through each of the convergence coils can be adjusted in amplitude and phase. The phase is adjusted by varying the horizontal tilt controls (L122, L123, and L124). These controls, combined with associated capacitors, form a circuit which is resonant at the line frequency. The parabolic wave is produced by applying the pulse from the horizontal flyback transformer to this resonant circuit. The amplitude of the wave is controlled by the horizontal amplitude controls. These controls vary the amplitude of the ringing pulse which, in turn, affects the wave amplitude.

Section IV. SUMMARY AND REVIEW

113. SUMMARY

a. In the color picture tube, the electron beams must strike only their respective color-phosphor dots, and the beams must pass through the same holes in the shadow mask at the same time.

b. The electrons are emitted by the cathode and accelerated by grid number.

c. The beams must be in perfect alignment with each other and with the central axis of the tube before passing through the convergence field. The convergence magnets and the purity coil are used to obtain these conditions.

d. The three beams are brought into focus by grid number 3 and pass through the shadow mask to the phosphor dot screen.

e. Since the beams are constantly being deflected across the face of the tube, they must be controlled so that they converge at the shadow mask regardless of the varying distance from the point of deflection to the shadow mask. This is done by varying the strength of the convergence field at the horizontal and vertical scanning rates.

f. By applying ac voltages at the scanning rate to the focus electrodes, dynamic focus can be obtained.

g. A purity error occurs when the electron beams do not pass through the center of deflection of the yoke. The effect is improper shading. It is corrected by the use of a purifying coil.

h. Static convergence is produced by the difference of potential between the converging electrode and the second anode.

i. Dynamic convergence is accomplished by decreasing the deflection angle of the electron beam. The voltage on the convergence anode must change with beam deflection.

j. Accurate focusing is accomplished by adding a portion of the dynamic convergence voltage to the dc focusing voltage.

k. Purity, convergence, and focusing are necessary for proper operation of a tri-color kinescope.

l. The horizontal and vertical deflection section, which includes the high-voltage circuits, is used to provide deflection yoke voltages and specific anode voltages.

m. The first video amplifier provides synchronization signals for horizontal and vertical deflection.

n. The height control is used to adjust vertical deflection. The vertical linearity control permits adjustment for a constant rate of beam movement down across the face of the kinescope.

o. The horizontal deflection and high-voltage circuits are composed of the horizontal oscillator and control circuit, the horizontal sweep output, high- and focus-voltage sources, and horizontal pulse source.

114. REVIEW QUESTIONS

a. What constitutes the convergence force in a color picture tube which employs a convergence element? Why are beam-positioning magnets used with this type of tube?

b. What advantage, with respect to convergence, is gained by use of a curved instead of a flat mask and screen?

c. What is meant by static and dynamic convergence?

d. What is the difference between purity, convergence, and focus?

CHAPTER 8

ADJUSTMENT AND ALIGNMENT OF COLOR TELEVISION RECEIVERS

Section I. INTRODUCTION

115. GENERAL

This chapter discusses the adjustment and alignment of a color television receiver. Although emphasis is placed on problems relating specifically to the adjustment and alignment of a color receiver, a brief review of procedures common to all television receivers is included. All of the procedures are presented in as general a manner as possible so that the underlying principles may be applied to any color receiver. However, when specific details are given, they apply to the receiver shown in figure 36.

116. OUTSIDE CABINET CONTROLS

a. In addition to the operating controls available on monochrome receivers, the color receiver has a hue control and a color control. The hue control enables the hue of color scenes to be changed; the color control permits the saturation of the colors in the scene to be varied.

b. There are also a number of controls which normally do not require adjustment. These may include the vertical convergence shape, the horizontal and vertical convergence amplitude, the green and blue background, the green and blue video gain, the red, green, and blue screen, vertical linearity and height, agc, and sound level controls.

117. RECEIVER SETUP CONSIDERATIONS

a. The receiver must first be set up for proper black-and-white reception. The following controls will have to be adjusted: height, vertical linearity, width, focus, centering, and horizontal hold. If the receiver is overloading, it will be necessary to adjust the agc control and the noise threshold control.

b. Since the color receivers incorporate a tricolor kinescope, the following must be adjusted for good black-and-white pictures, free of color fringing: convergence controls, purity magnets, and screen grid controls. The techniques used in making kinescope circuit adjustments constitute the major difference between the setup procedures for black-and-white and color television receivers.

Section II. COLOR RECEIVER OPERATION

118. PROGRAM TUNING PROCEDURE

a. Turn the on-off switch clockwise to midposition and allow the set approximately 30 seconds to warm up. Turn the contrast control clockwise at least one-quarter turn. Select a channel on which a color program is being telecast.

b. Turn the brightness control fully counterclockwise then slowly clockwise until a picture appears. If the picture is not stable, adjust the horizontal and vertical hold controls. Turn the fine tuning control to the extreme counterclockwise position for uhf tuning channels (the extreme clockwise position for vhf channels) until the picture starts to disappear. Then turn it back slowly until the point is reached where the sound bars have just disappeared.

c. Color should be present now. Advance the color control at least one-quarter turn and adjust the hue control until pleasing flesh tones are present or the color of some familiar object (such as grass) appears natural. Readjust the color control for the desired saturation, then alternately adjust the hue and color controls for optimum color presentation.

d. If color fringes appear on large objects during black and white reception, adjust the convergence control on the outside of the cabinet for minimum fringe in the center of the picture. If the picture is blurred, adjust the focus control.

e. Select the tone preference (bass, normal, treble) by adjusting the tone control. If a 920-kc interference pattern is noticeable during a color telecast, adjust the fine tuning control until it disappears.

119. GENERAL

a. Alignment of the circuits in a color receiver is more complex than in a black and white receiver because there are more circuits involved and the alignment requires more care and precision. Circuit response curves, acceptable for monochrome reception, are not always satisfactory for color reception. Circuits requiring alignment are the rf, the picture i.f., the sound i.f., the video amplifier-detection, and the chrominance synchronization sections.

b. Most of the equipment required for alighment is the same as that used in aligning black-and-white receivers. In making the overall picture i.f. alignment, a sweep generator is used. It should produce a sweep that is linear and assures reproduction of a response curve that can be made linear. The sweep generator should also produce accurate sound- and picture-carrier markers.

120. PRELIMINARY PROCEDURE

Remove the fuse in the horizontal deflection circuit before aligning the sound i.f., picture rf and i.f., and video sections of the receiver. This will prevent horizontal pulse interference on the oscilloscope. Connect a 2500-ohm, 100-watt resistor from the B-plus to ground. Turn the agc control (R103-B) fully clockwise and the focus control counterclockwise; then connect a bias box similar to that shown in figure 55 to the grid of the bandpass amplifier (V701-A), and adjust the bias supply for -8 volts.

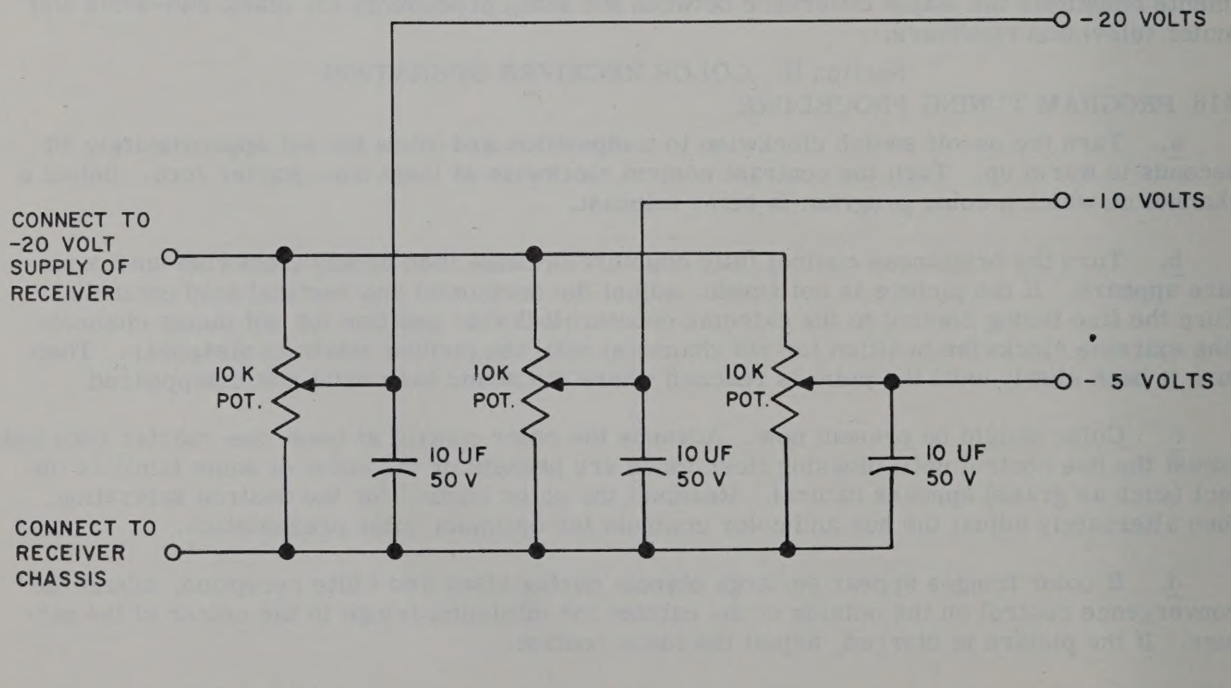


Figure 55. Bias supply.

121. SOUND I. F. ALIGNMENT

Remove the shield over the picture i.f. section, and connect a signal generator to the output side of the sound detector (terminal F of the video i.f. section). Connect two matched 100,000-ohm resistors in series from test point TP202 (fig. 36) to ground. Connect a vacuum-tube voltmeter (vtvm) from test point TP202 to ground. Set the signal generator at 4.5 mc with maximum output, and adjust the sound take-off transformer (T201) and the top and bottom of the ratio-detector transformer (T202) for maximum indication on the vtvm (par. 70). After peaking this transformer, adjust the signal level from the signal generator for -12 volts on the vtvm. This is approximately the operating level of the ratio detector (V202-A) for average signals. Disconnect the vtvm from TP202 and connect it to test point TP201. Connect the ground lead of the vtvm to the junction between the two 100,000-ohm resistors. Tune the ratio-detector secondary (bottom) for zero dc on the vtvm. Remove the resistors, signal generator, and vtvm from the circuit.

122. VIDEO 4.5-MC TRAP ADJUSTMENT

Connect a jumper lead from the grid of the third picture i.f. amplifier (V303) to ground. Connect the signal generator to the grid of first video amplifier (V401-A), and set the generator at 4.5 mc with internal modulation. Using the diode probe, connect the oscilloscope to terminal "D" of the bandpass transformer (T702) in the grid circuit of the demodulators, and adjust the bottom of the chroma take-off transformer (T701) in the grid of the bandpass amplifier for a minimum indication on the oscilloscope (par. 71b). A bias of -8 volts should be present at the grid of the bandpass amplifier, but it may have to be made more positive to obtain an indication on the oscilloscope large enough to be observed. Disconnect the jumper lead from the grid of the third picture i.f. amplifier, and remove the oscilloscope and the signal generator from the circuit. Replace the shield on the picture i.f. section.

123. PICTURE I. F. TRANSFORMER ADJUSTMENTS (Par. 69)

a. Broadband Adjustment of the First Picture I. F. Connect the sweep generator in series with a 1500-uuf ceramic capacitor to the control grid of the first picture i.f. amplifier (V301), and set the generator for a frequency range such as to obtain a signal output which resembles the i.f. response curve. Couple the signal generator loosely to the first picture i.f. amplifier grid in order to obtain markers. Connect the -10 volt lead of the bias box shown in figure 55 to terminal "B" of PW300 (fig. 36), and adjust the bias supply for -9 volts of i.f. bias. Short terminal "C" of PW400 to ground. Connect one of the load leads of the i.f. test block, shown in figure 56, to the plate of the third picture i.f. amplifier (V303). Connect the detector lead of the i.f. test block to the plate of the second picture i.f. amplifier (V302), and connect the oscilloscope to the oscilloscope terminals of the test block. Insert markers at 42.17 and 45.75 mc with the signal generator, and adjust the top and bottom of the first picture i.f. transformer (T301) for the response shown in figure 57A. Adjust the oscilloscope for 0.1 volt peak-to-peak amplitude when making.the adjustment. Remove the i.f. test block, the sweep and signal generators, and the oscilloscope from the circuit.

b. Set-up for Remaining Picture I. F. Adjustments. Connect the oscilloscope in series with a 10,000-ohm composition resistor to the control grid of the first video amplifier. Set the sound-rejection control (R312) in the third picture i.f. transformer circuit to midposition. Connect the signal generator in series with a 1500-uuf ceramic capacitor to the mixer grid (TP2 in fig. 36). Keep the leads as short as possible, and keep the shield of the picture i.f. section in place for the adjustments that follow.

c. Stagger-Tuned Adjustment for Picture I. F. Transformers. Set the signal generator to each of the following frequencies, and tune the specified transformer for maximum indication on the oscilloscope. In each instance, check the generator against a crystal calibrator to insure that the generator is on the proper frequency.

45.75 mc	Converter transformer (T2)
45.75 mc	First picture i.f. coil (L301)
52.50 mc	Second picture i.f. transformer (T302)
43.80 mc	Third picture i.f. transformer (T303) (bottom core)

d. Trap Adjustments in the Picture I. F. Circuits. Set the signal generator to each of the following frequencies, and adjust the specified components for minimum indication on the oscilloscope:

41.25 mc	L102 (fig. 36)
47.25 mc	L103 (fig. 36)
41.25 mc	Third picture i.f. transformer (T303) (top core)
41.25 mc	Sound-reject resistor (R312)

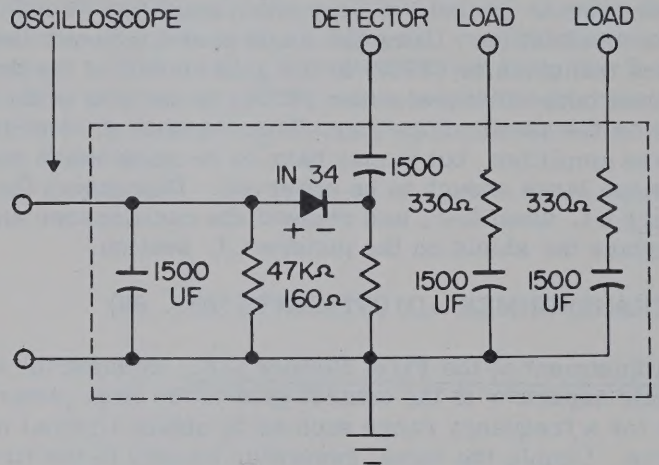

OSCILLOSCOPE
DETECTOR
LOAD
LOAD
IN 34
1500
330Ω
330Ω
+ −
1500 UF
47KΩ
160Ω
1500 UF
1500 UF

Figure 56. I.f. test block.

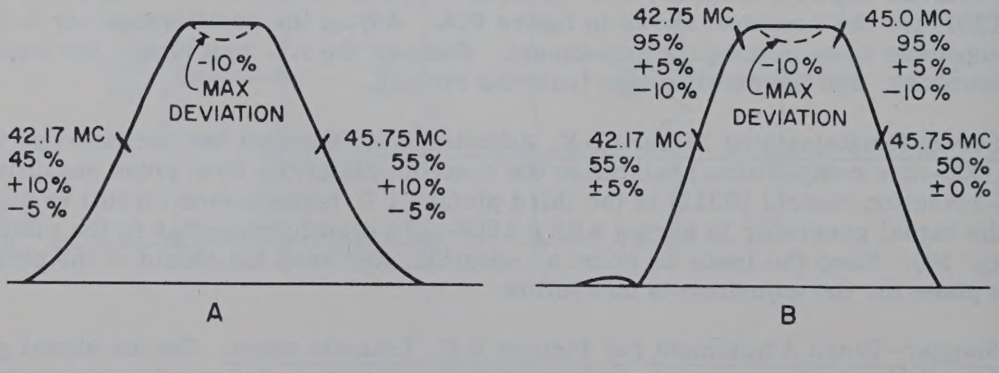


Figure 57. Overall response curves.

e. Readjustment of the Third Picture I. F. Transformer. Recheck the adjustment of the third picture i.f. transformer (bottom core) for maximum indication at 43.80 mc after making the above adjustment.

124. SWEEP ALIGNMENT OF PICTURE I. F. (Par. 69)

a. Set-up for Sweep Alignment. Remove the signal generator. Connect the sweep generator through a 1500-uuf ceramic capacitor to TP2 in the mixer grid circuit (fig. 36). Use the shortest leads possible; do not leave more than one-half inch of unshielded lead at the end of the sweep cable. Connect the sweep generator ground lead to the top of the tuner case. Set the channel selector switch to channel 4.

b. Readjustment of Picture I. F. Circuits. Connect the -5 volt lead of the bias box shown in figure 55 to the agc input terminal of the rf tuner, and adjust this supply for -4 volots of bias. The bias at the grid of the first picture i.f. amplifier (V301) should remain at -9 volts. Couple the signal generator to the first picture i.f. amplifier grid to provide markers of 42.17, 42.75, 4.5, and 45.75 mc. The output from the generator should be kept as low as possible and still provide markers on the response curve. With the oscilloscope still connected to the grid of the first video amplifier, the curve should resemble that shown in figure 57B. Use 3 volts peak-to-peak on the oscilloscope when checking the response. Slight readjustments of the converter transformer (45.75 mc), the second picture i.f. transformer (52.50), and the third picture i.f. transformer bottom core (43.80 mc) may be made to obtain the proper response. Recheck the sound-rejection control (R312) and the third picture i.f. transformer (top core) for minimum indication on the oscilloscope at 41.25 mc.

c. Video I. F. Sweep Alignment. Connect the oscilloscope to the output of the sound detector in the i.f. section. Connect the output cable of the sweep generator to one side of the 22db pad (fig. 58A), and the sweep termination pad (fig. 58B) to the other side of the 22 db pad.

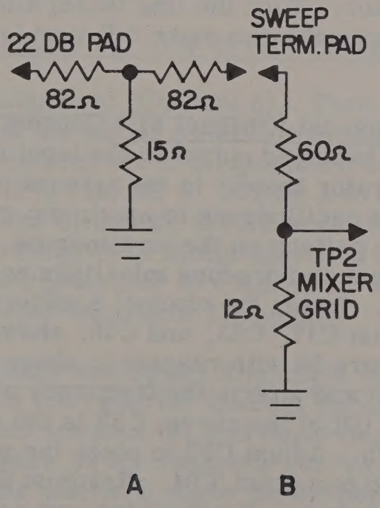


Figure 58. Attenuation pads.

Connect the sweep termination pad to TP2 as indicated. With the signal generator still coupled to the first picture i.f. amplifier grid, insert a 45.75-mc (picture carrier frequency) marker. Adjust the sweep and oscilloscope for 1 inch of deflection between the base line and the picture carrier marker. Mark the base line and the picture carrier marker points on the oscilloscope. Remove the 22-db pad from the sweep output, but leave the sweep termination pad connected. Move only the oscilloscope centering controls, and place the base line at the base line point previously marked. Move the trace horizontally to place the 41.25-mc sound signal opposite the 1-inch point previously marked. The i.f. bias at terminal "B" of PW300 (figure 36) may have to be lowered to obtain an indication on the oscilloscope. Adjust L102, the 41.25-mc trap in figure 36, until the bottom of the mark is on the picture carrier mark (1 inch from the base line).

125. RF TUNER ALIGNMENT (Par. 68)

a. Set-up for RF Tuner Alignment. An rf tuner which is operative and requires only touch-up adjustments does not require the preliminary adjustments outlined in this paragraph. For rf tuners which are completely out of adjustment, set the fine tuning adjustment (C33) fully counterclockwise. Turn the oscillator slugs for channels 7 to 13 fully clockwise then back one full turn. Do not change any adjustment in the antenna matching unit.

b. Oscillator Injection Voltage Alignment. Disconnect the cable that couples the output of the rf tuner to the i.f. section, and connect a 39-ohm composition resistor from the rf tuner output to ground. Short the agc input terminal of the rf tuner to ground. Connect a 56-ohm composition resistor from ground to the point where the fm trap in the antenna matching unit connects to the rf tuner. Set the channel selector switch to channel 8. Connect the vtvm to TP1 shown in figure 36, and adjust C28 until a reading of -3.5 volts appears on the vtvm. The limits for the oscillator injection voltage are -2.5 volts minimum and -5.5 volts maximum. Remove the vtvm.

c. RF Section Fine-Tuning Control Adjustment. Turn the fine-tuning control on the outside of the cabinet fully clockwise. Connect the oscilloscope to the rf tuner output, and tune the signal generator to 227 mc, using a crystal. Insert one end of a piece of insulated wire into the tuner unit through the hole provided for the adjustment of C23. Do not let the wire touch any of the tuned circuits as it may cause the frequency of the tuner oscillator to shift. Connect the other end of the wire to the rf input terminal of the signal generator. Adjust C29 to obtain a zero beat with the signal generator. Turn the fine tuning adjustment (C33) clockwise until the beat just begins to change, then make one more full turn (clockwise). Turn the fine tuning control to midposition.

d. RF Oscillator Sweep Alignment (Channel 8). Connect the output of a sweep generator providing an attenuated, 300-ohm balanced output to the input terminals of the antenna matching unit. Connect the signal generator loosely to the antenna terminals. Set the sweep generator to cover channel 8. Set the oscilloscope to maximum gain and use the minimum input signal which will produce a usable pattern on the oscilloscope. Excessive input can change oscillator injection during alignment and produce misalignment even though the response on the oscilloscope may look normal. Insert the channel 8 picture and sound-carrier markers (181.25 mc and 185.75 mc). Adjust C17, C23, and C26, shown in figure 36, until the response curve resembles that shown in figure 59 with respect to shape, frequency, and bandwidth. C17 tunes the rf amplifier plate circuit and affects the frequency of the pass band; C26 tunes the mixer grid circuit and affects the tilt of the curve; C23 is the coupling adjustment and primarily affects the response bandwidth. Adjust C23 to place the markers at the 100-percent level on the curve. Connect the vtvm to test point TP1. Readjust C28 for an oscillator injection voltage of -3.5 volts. Remove the vtvm. Readjust the unit as outlined in this subparagraph until the proper response is obtained.

e. Oscillator Injection Voltage and Sweep Alignment (Channels 7-13). Set the receiver channel switch and the sweep generator to channel 13. Adjust the signal generator to insert the channel 13 sound and picture carrier markers (211.25 mc and 215.75 mc). Adjust L42 and L28 until the markers appear at the 100-percent level. Turn off the sweep and signal generators, and connect the vtvm to test point TP1 to check that the oscillator injection voltage is within limits as previously specified (-2.5 volts minimum, -5.5 volts maximum). If it was necessary to readjust C28 to bring it within range, turn the sweep and signal generators back on and recheck the channel 13 response, readjusting L42 and L28 if necessary. Set the sweep generator and signal generator to cover channel 8, and readjust C26, C23, and C17 for the correct curve response with respect to shape, frequency, and bandwidth, if necessary. Turn off the sweep and signal generators, switch back to channel 13, and check the oscillator injection voltage to TP1 if C26 was adjusted in the recheck of channel 8 response. If the initial setting of the oscillator injection trimmer required other than a slight adjustment, it may be necessary to adjust the oscillator frequency and response on channel 8. Repeat the adjustments described thus far in this paragraph until the oscillator injection voltage is obtained. Check the response on channels 7 through 13 to insure that all channels are within limits with respect to tilt and bandwidth, as shown in figure 59, and injection voltage as specified in subparagraph b.

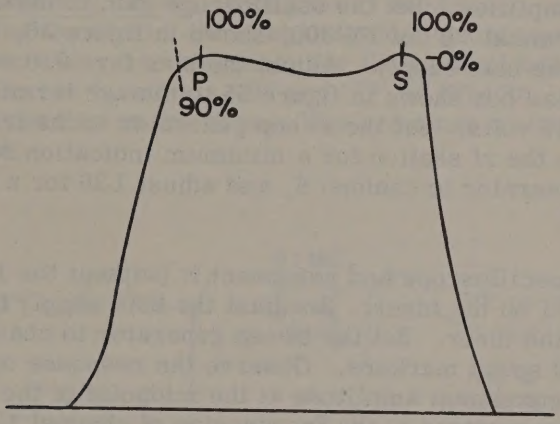


Figure 59. Vhf rf tuner response.

f. RF Oscillator Sweep Alignment (Channel 6). Turn off the sweep generator, switch the receiver to channel 6, and adjust the signal generator to the channel 6 oscillator frequency (129 mc). With the fine-tuning control set to midposition, adjust L61 for a zero beat. Turn the sweep generator on and set it to channel 6. Adjust L40 and L54 for proper curve shape as shown in figure 59. The maximum allowable deviation is 20 percent. Recheck the oscillator injection voltage at TP1 to insure that it is within specified limits. If C28 requires adjustment, switch the receiver and the signal generator to channel 8. Readjust C26 for correct curve shape and recheck C29 and C33 for proper oscillator frequency.

g. Oscillator Injection Voltage and Sweep Alignment (Channels 2-6). Check the response of channels 2 through 6 by setting the receiver channel switch, sweep generator, and marker generator to each of these channel frequencies and observing the response and oscillator injection voltage obtained. See figure 59 for response curves. Each of these channels should have the proper response with the markers above the 85-percent response level and a deviation of not more than 20 percent. If the markers are not within these limits, readjust L40 and L54. Knife (increase, decrease, or otherwise alter the spacings between the windings of a coil) the windings of coils L36 to L39 and L50 to L53 to achieve minimum tilt on channels 5 through 2. Always knife coils from the highest channel to the lowest to avoid affecting the tuning of the channels above the one being knifed.

h. Readjustment of Oscillator Injection Voltage and Sweep Alignment (Channels 7-13). Switch the channel selector, signal generator, and marker generator through channels 7-13, and observe the response curves. Refer to figure 59 for the proper waveform. Check that the injection voltage at each channel is within limits. If necessary, readjust C17 or C16 to obtain the proper response. With the receiver and the signal generator on channel 13, adjust L49 for a zero beat with the signal generator.

i. RF Oscillator Alignment. Adjust the oscillator to the proper frequency on all channels by switching the receiver and the frequency standard to each channel and adjusting the appropriate oscillator slug to obtain a zero beat. It should be possible to adjust the oscillator for a zero beat on each channel. Recheck the oscillator injection voltage on each channel to verify that the voltage is within the specified limits. Remove the 39-ohm resistor from the rf tuner output, and reinsert the connecting cable to the i. f. section.

j. RF Amplifier Bandpass Alignment.

(1) Connect the oscilloscope in series with a 10,000-ohm resistor and the grid of the first video amplifier. Set the oscilloscope gain to maximum. Connect a bias source to terminal "B" of PW300, shown in figure 36, and ground the positive terminal of the bias supply. Adjust the bias for -9.0 volts. Connect the -20 volt lead of the bias box shown in figure 55 to the agc terminal of the tuner and set the supply for -15 volts. Set the sweep generator to the frequency of channel 13, and adjust L21 in the rf section for a minimum indication on the oscilloscope. Switch the sweep generator to channel 6, and adjust L26 for a minimum indication on the oscilloscope.

(2) Remove the oscilloscope and reconnect it (without the 10,000-ohm resistor) to test point TP1 on the tuner. Readjust the bias supply for -4.0 volts at the agc terminal on the tuner. Set the sweep generator to channel 8, and insert channel 8 picture and sound markers. Observe the response on the oscilloscope, and adjust C12 for maximum amplitude at the midpoint of the curve. Switch the sweep and marker generators to the frequencies of channel 13, and adjust L12 (knife coil) for maximum amplitude at the midpoint of the curve. Switch back to channel 8 and readjust C12; then switch back to channel 13 and readjust L12.

(3) Connect the oscilloscope in series with the 10,000-ohm resistor and the grid of the first video amplifier, and increase the bias at the agc terminal to -15 volts. On channel 13, readjust L21 for a minimum indication on the oscilloscope; on channel 6, readjust L26 for a minimum indication. Connect the oscilloscope to test point TP1, and reset the bias supply for -4.0 volts at the agc terminal. Adjust C12 on channel 8 and L12 on channel 13 for maximum amplitude at the midpoint of the response curve. Switch the sweep and signal generators to channel 6. Adjust L17 for maximum amplitude at the midpoint of the curve. Switch through channels 13 to 2 and observe the response. The deviation at the midpoint of the curve should not exceed the 85-percent level on any channel; if this figure is exceeded, it will be necessary to knife coils L7 through L11 and L13 through L16. Knife the coils by starting at the highest channel and proceeding to the lowest.

126. VIDEO AND BANDPASS ALIGNMENT

a. Setup for Video and Bandpass Alignment. Set the channel selector to the vhf channel with the least deviation in the response. Connect one output of the bias supply to the agc terminal on the tuner and adjust the supply for -4.0 volts on the vtvm. Connect a second output of the bias supply to terminal "B" of PW300, and adjust the supply for a bias of -9.0 volts at terminal "B." Connect a -100 volt bias source to the grid of the burst keyer tube. The bias at the control grid of the bandpass amplifier should be -8.0 volts. Turn the killer threshold control fully counterclockwise.

b. Alignment of the Driver Primary and Secondary Transformers (par. 74). Using an rf probe, connect the vtvm to the cathode of the G-Y demodulator. The vtvm should indicate between 0 and 20 volts. If there is no indication on the vtvm, the 3.58-mc-oscillator is not operating and the burst amplifier transformer should be adjusted. Connect the vtvm to terminal "C" of the driver primary transformer, and adjust the top and bottom cores for maximum indication on the vtvm. Connect the vtvm to terminal "C" of the driver secondary transformer, and adjust the top and bottom cores for a maximum indication.

c. RF Oscillator Frequency Check. Connect the oscilloscope (using the diode probe) and the signal generator to the cathode of the first video amplifier. Set the signal generator to the oscillator frequency of the selected channel. Connect one end of an insulated wire to the rf input terminal of the generator, and insert the free end into the tuner at the opening designed for the adjustment of C23. Adjust the fine-tuning control to obtain a zero beat with the signal generator. The zero beat indicates that the oscillator is exactly on frequency.

d. Video Carrier Frequency Check. Using the rf modulator, connect the sweep and signal generators to the antenna terminals; then set the sweep generator for video sweep. Set the signal generator to the picture-carrier frequency for the channel being used. Using the diode probe, connect the vtvm between terminals "B" and "D" of PW400. Adjust the output from the generators for a -1.5-volt reading on the vtvm. The response on the oscilloscope will resemble that shown in figure 60A.

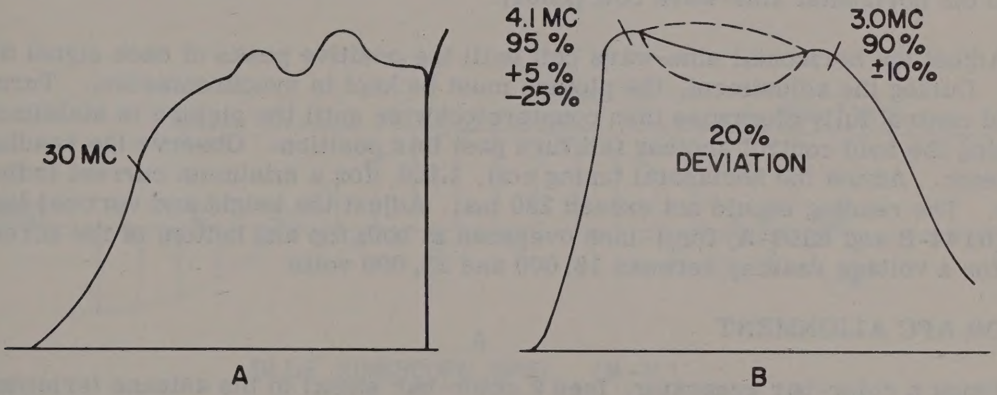


Figure 60. I.f. and video response.

e. Alignment of the Bandpass and Color Take-off Transformers (par. 73). Disconnect the oscilloscope and diode probe from the first video amplifier and reconnect it to terminal "F" of the bandpass transformer. Load the transformer by connecting a 330-ohm, 1-watt resistor across terminals "F" and "B." Adjust the bottom core of color take-off transformer T701. Remove the 300-ohm load on the bandpass transformer, and connect the oscilloscope, using the diode probe, to terminal "D." Adjust the top and bottom cores of the bandpass transformer for the correct waveform shown in figure 60B. If the proper response cannot be obtained, remove the top core from the coil, and insert the core in the opposite end of the coil. Connect the oscilloscope to each of the kinescope control grids. The response curves from each should resemble those shown in figure 61. Any unusual deviation from these response curves indicates improper operation of the demodulator circuits. Remove all bias sources, the 2500-ohm resistor loading the B- plus, and the oscilloscope. Replace the fuse in the horizontal deflection circuit.

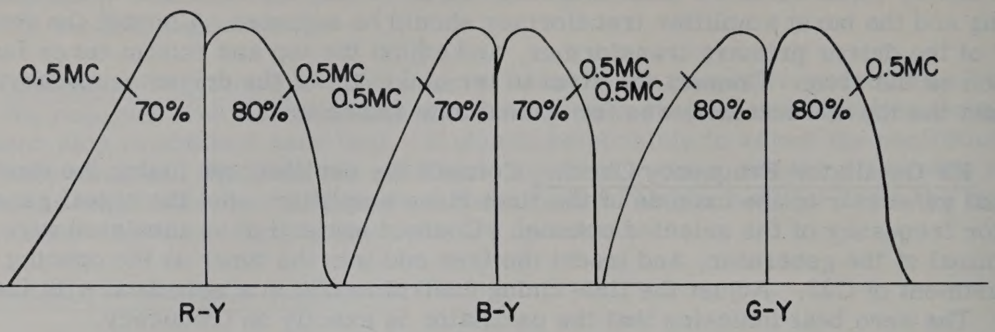


Figure 61. Color difference signals at the kinescope.

127. HORIZONTAL DEFLECTION ALIGNMENT

a. Connect a milliammeter (0- to 500-ma range) across the terminals of the fuse in the horizontal output tube circuit. Using the high-voltage probe, connect the vtvm to the cup at the base of the high-voltage rectifier. Set the width control (L107) to midposition. Using a low-capacity probe, connect the oscilloscope to the junction between the horizontal hold control (L118) and the horizontal sine-wave coil (L601).

b. Adjust the horizontal sine-wave coil until the positive peaks of each signal are equal in height. During the adjustment, the picture must be kept in synchronization. Turn the horizontal hold control fully clockwise then counterclockwise until the picture is stabilized. Continue turning the hold control another full turn past this position. Observe the reading on the milliammeter. Adjust the horizontal tuning coil, L106, for a minimum current indication on the meter. The reading should not exceed 220 ma. Adjust the height and vertical linearity controls (R144-B and R108-A) for 1-inch overscan at both top and bottom of the screen. Check the vtvm for a voltage reading between 18, 000 and 22, 000 volts.

128. COLOR AFC ALIGNMENT

a. Using a color-bar generator, feed a color-bar signal to the antenna terminals of the color receiver for afc alignment. Connect a vtvm between the meter terminal of the color-bar generator and ground. Set the metering switch to the subcarrier position and the subcarrier amplitude control to maximum. A reading of approximately -1. 2 volts should be obtained on the vtvm. Set the metering switch to the synchronization position and adjust the synchronization amplitude control for a reading of -1. 5 volts on the vtvm. Turn the 60-cycle modulator switch to the on position. The reading on the vtvm should increase to approximately -1. 85 volts. Turn the metering switch and the 60-cycle modulation switch to the off position.

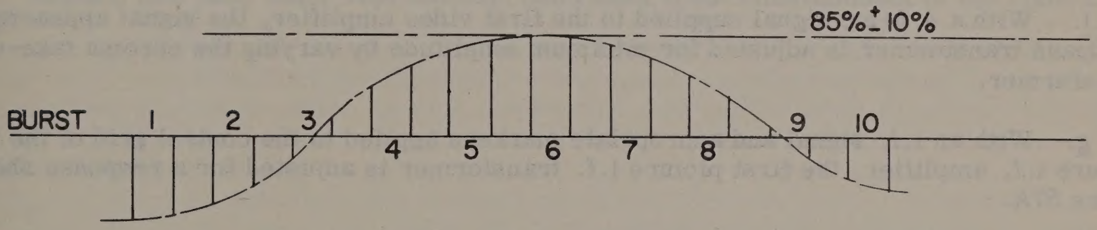
b. Turn the channel selector on the color receiver to 3, and adjust the horizontal hold control of the generator for a stable bar pattern on the receiver kinescope. Adjust the receiver fine-tuning control until sound interference disappears from the picture on the kinescope. Adjust the receiver color control (R116) until color appears in the bar pattern. If the receiver picture width is properly adjusted, 10 bars will appear on the kinescope.

c. Connect a vtvm to terminal C of the cw driver primary transformer (T705). With the receiver color and contrast control at midposition and the 3. 58-mc oscillator operating (refer to par. 126b), adjust the primary transformer for maximum indication on the vtvm. Connect the vtvm to terminal C of the cw driver secondary transformer (T706) and repeat the adjustment procedure performed on the primary. Turn the color control fully clockwise and ground terminal A of the bandpass transformer. Adjust the burst-amplifier transformer (T704) for zero beat on the kinescope. Return the color control to midposition.

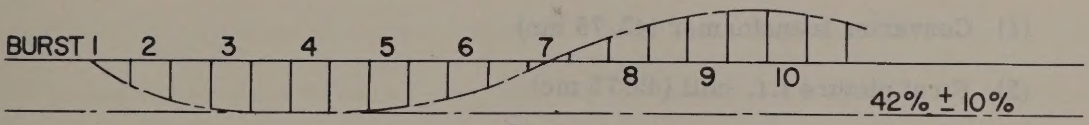
d. Connect the vtvm to terminal C of the burst-keyer transformer (T103). Set the hue control (R164) fully counterclockwise and connect it to ground through a 150-uuf capacitor. Connect the oscilloscope to the blue kinescope control grid. Adjust the burst-keyer transformer for maximum indication on the vtvm. Remove the 150-uuf capacitor from the hue control and set the control to midposition.

e. Connect the vtvm to terminal C of the cw driver secondary transformer and observe the voltage. With the oscilloscope still connected to the blue kinescope control grid, turn the hue control back and forth from one maximum position to another, and observe the bar pattern. The sine-wave pattern shown in figure 62A should vary symmetrically above and below the horizontal axis at the third bar (cancellation). The bottom core of the cw driver primary transformer should be adjusted to produce this result. Turn the hue control until the sine wave passes through the horizontal axis at the third bar. The voltage present on the vtvm should not vary by more than 1.5 volts as a result of this adjustment.

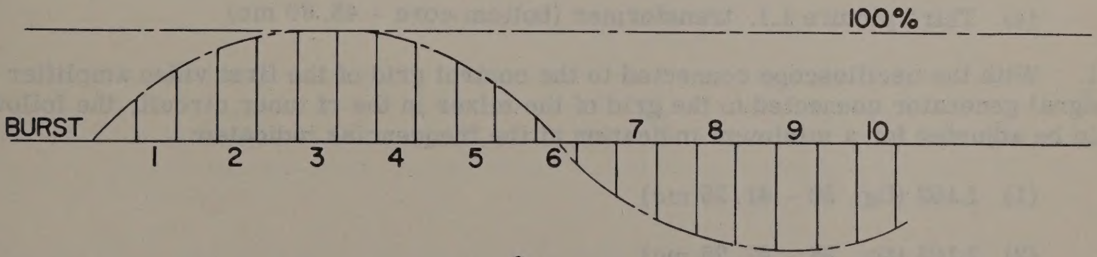
f. Connect the vtvm to terminal C of the cw driver primary transformer and observe the voltage. Connect the oscilloscope to the control grid of the green electron gun, and adjust the top core of the cw driver primary transformer for cancellation of the first and seventh bars as shown in figure 62B. Move the oscilloscope to the control grid of the red electron gun and check for cancellation of the sixth bar as shown in figure 62C. A slight adjustment of the top core of the cw driver primary transformer may be necessary. The voltage indicated on the vtvm should not have changed by more than 1.5 volts.



A
BLUE KINESCOPE GRID (B-Y)



B
GREEN KINESCOPE GRID (G-Y)



C
RED KINESCOPE GRID (R-Y)

Figure 62. Waveforms at the kinescope control grids.

g. Observe the amplitude of the signal on the oscilloscope while it is connected to the control grid of the red electron gun, and consider the amplitude of this signal 100 percent. Connect the oscilloscope to the control grid of the blue electron gun. The amplitude of this signal should be 85 percent (±10 percent). Connect the oscilloscope to the control grid of the green electron gun. The amplitude of this signal should be 42 percent (±10 percent).

Section IV. SUMMARY AND REVIEW

129. SUMMARY

a. All operating controls of a black and white receiver are found on a color receiver. Almost all of the operating and setup controls are accessible from the outside of the cabinet.

b. The receiver should first be set up for proper black and white operation with the conventional adjustments. Purity, convergence, and color should also be checked.

c. To receive black and white programs, the contrast, brightness, and fine-tuning controls should be adjusted.

d. To receive color programs, the contrast, brightness, fine-tuning, color, hue, convergence, focus, and tone controls should be adjusted.

e. The sound take-off and ratio-detector transformers are aligned at 4. 5 mc for a maximum indication on the vtvm.

f. With a 4. 5-mc signal supplied to the first video amplifier, the signal appearing at the bandpass transformer is adjusted for minimum amplitude by varying the chroma take-off transformer.

g. With an i. f. signal and appropriate markers applied to the control grid of the first picture i. f. amplifier, the first picture i. f. transformer is adjusted for a response shown in figure 57A.

h. With the oscilloscope connected to the control grid of the first video amplifier and the signal generator connected to the grid of the mixer in the rf tuned circuit, the following should be adjusted for a maximum indication at the frequencies indicated:

(1) Converter transformer (45. 75 mc)

(2) First picture i. f. coil (45. 75 mc)

(3) Second picture i. f. transformer (52. 50 mc)

(4) Third picture i. f. transformer (bottom core - 43. 80 mc)

i. With the oscilloscope connected to the control grid of the first video amplifier and the signal generator connected to the grid of the mixer in the rf tuner circuit, the following should be adjusted for a minimum indication at the frequencies indicated:

(1) L102 (fig. 36 - 41. 25 mc)

(2) L103 (fig. 36 - 47. 25 mc)

(3) Third picture i. f. transformer (top core - 41. 25 mc)

(4) Sound-reject control (41. 25 mc)

j. The signal appearing at the grid of the first video amplifier during the sweep alignment of the picture i.f. section should resemble the response shown in figure 57B.

k. The output of the rf tuner should resemble the response curve shown in figure 59 on all channels.

l. The signal at the cathode of the first video amplifier should resemble the response curve shown in figure 60A.

m. The signal at terminal F of the bandpass transformer should resemble the response curve shown in figure 60B.

n. The signals at the kinescope control grids should resemble those shown in figure 61.

o. Proper alignment of color afc is indicated by cancellation of the sine waves as shown in figure 62.

130. REVIEW QUESTIONS

a. How does the bandpass amplifier alignment in a color receiver differ from monochrome video amplifier alignment?

b. How does the response of the rf and i.f. sections of a color receiver differ from that of a monochrome receiver?

c. Explain how poor color reproduction can result from misalignment of the video i.f. section?

CHAPTER 9

COLOR TELEVISION TEST EQUIPMENT AND SERVICING

Section I. TEST EQUIPMENT

131. INTRODUCTION

In addition to the test equipment used on black-and-white receivers, the color-bar generator and the dot-bar generator are necessary for analyzing and aligning a color television receiver. A wide-band oscilloscope with a flat frequency response to 4. 5 mc for reproduction of 3. 58-mc synchronization burst and oscillator signals is desirable for certain applications. While all test equipment may not have the specific controls and parameters of the equipment discussed in this section, they all function alike.

132. COLOR-BAR GENERATOR

a. A color-bar generator is used to check the overall operation and alignment of color receivers. This generator produces 10 parallel bars of different colors on the kinescope. Each bar is spaced at 30-degree phase intervals which correspond to the R-Y, B-Y, G-Y, I, and Q axes. The color bar generator provides crystal-controlled color subcarrier, picture carrier, and sound carrier frequencies on channel 3. Crystal-controlled horizontal synchronization and bar frequencies are also provided.

b. The unmodulated sound carrier is included to ensure precise tuning of the receiver, to check sound rejection, and to check for the presence of beat interference between the color subcarrier and the sound carrier. The color bar generator can be used to eliminate the sound carrier temporarily for quick identification of sound interference.

c. Luminance signals are provided at the edges of the color bars to check the registration of the luminance and chrominance signals. The color-bar generator is capable of injecting brightness. Brightness signal injection provides a means to check for a possible shift of hue in the bright areas or highlights. The amplitude of the color subcarrier and burst are adjustable to provide a positive check on the color synchronizing lock in the receiver.

d. Color video signals of positive or negative polarity are provided for both low-impedance (75 ohms) and high-impedance (3000 to 5000 ohms) video circuits. The high-impedance output signals are valuable in localizing trouble in the second detector. A rectifier circuit, used in conjunction with a vtvm, facilitates measurement and adjustment of synchronization and subcarrier signal amplitudes in the receiver.

133. DOT-BAR GENERATOR

a. The dot-bar generator provides a pattern of rectangular dots which is used in making all convergence adjustments in color receivers. The dot-bar generator also provides cross-hatch patterns, horizontal bars, and vertical bars which are used in making linearity adjustments in color and monochrome receivers. The number of bars may be varied: 8 to 15 horizontal bars and 11 to 13 vertical bars.

b. Video and modulated rf output signals are provided. The rf output can be tuned to all frequencies from channel 2 to 6 inclusive. The amplitude of these signals is adjustable. Positive or negative video output of approximately 5 volts is provided for the video amplifier of color or black-and-white receivers. Choice of internal 60-cycle vertical synchronization or external synchronization is also provided.

134. WIDE-BAND OSCILLOSCOPE

The oscilloscope required to analyze and align a color television receiver must be of the wide-band variety and provide a flat response for frequencies up to 4.5 mc. Oscilloscopes which are adequate for use with black and white receivers may have a flat frequency response up to only 3 mc.

135. SWEEP GENERATOR AND CRYSTAL CALIBRATOR

a. The rf and i.f. amplifiers in color receivers must be aligned correctly to provide a flat response for modulating frequencies up to 4.1 mc.

b. When checking or aligning the rf and i.f. amplifiers in color receivers, use a reliable sweep generator and an accurate crystal calibrator. The sweep generator should provide fundamental frequencies in the rf and video-frequency ranges, flat voltage output, minimum standing waves on the output cable, wide-range attenuation, minimum leakage, and good linearity.

c. In black-and-white receivers, the video-frequency section consists of a one- or two-stage amplifier with no tunable peaking adjustments. Therefore, it is seldom necessary to check the response of the video amplifier in black-and-white receivers, except for reducing troubles that cause poor picture quality. In color receivers, however, there are a number of video frequency sections, including the video amplifier, the bandpass amplifier, demodulators, and the green, red, and blue matrix networks. A video sweep is essential in checking or aligning the tunable bandpass filter and the I and Q filters.

d. A crystal calibrator is essential for color television service because it ensures the accuracy required to locate the shoulder of the overall rf/i.f. response curve, the position of the picture carrier, and the exact frequencies for the i.f. traps.

136. VIDEO MULTIMARKER

a. Markers must be provided to identify specific frequencies on the response curves when using the video-frequency range of a sweep generator for certain applications, such as checking the response of a video amplifier, aligning the chrominance bandpass filter, or checking the I and Q channels.

b. It is possible to use a c-w oscillator as a marker, but this method is not recommended for video frequencies because the harmonics of the oscillator usually create a number of unwanted markers on the response curve, making it difficult to identify the desired point. For video-frequency work, use an absorption type of marker which consists of a tuned circuit loosely coupled to the output of the sweep generator. The tuned circuit absorbs a small amount of the sweep signal, producing a dip or notch in the response curve at a point corresponding to the resonant frequency of the tuned circuit.

c. A video multimarker should provide simultaneously five absorption markers accurately set at the following frequencies: 0.5 mc (for Q filter), 1.5 mc (for I filter), 2.5 mc (for bandpass filter), 3.58 mc (color subcarrier frequency), and 4.5 mc (sound-trap frequency).

137. HIGH-VOLTAGE PROBE

When installing and servicing black-and-white receivers, it is seldom necessary to measure the high voltage; the brightness of the raster and any noticeable "blooming" effect will usually indicate whether or not the voltage is adequate. In color receivers, however, it is necessary to adjust the high voltage to a specified value and check the high-voltage regulation. This requires an accurate voltmeter and high-voltage probe. High-voltage indicators of the spark or gas type are not recommended for color servicing.

Section II. RECEIVER SETUP PROCEDURE

138. INTRODUCTION

During the initial installation of a color receiver, the setup procedure outlined in this section should be accomplished. Following this procedure will ensure proper reception if there are no faulty circuits. If, after accomplishing the setup procedure, reception is poor, the troubles can be more easily isolated.

139. RF OSCILLATOR ADJUSTMENTS

a. Turn the channel selector to all available channels and adjust the fine tuning control for the best picture on each channel. The fine tuning control should be approximately at midposition when the receiver is properly tuned. If the fine tuning control is not at midposition, adjustments are required. Turn the fine tuning control to midposition and the channel selector to the highest channel received. Adjust the associated oscillator trimmer for best picture reception. When making the trimmer adjustments, procede from the highest to the lowest channel.

b. If interference from an fm signal appears in the picture, adjust the fm trap to minimize it. Check channels 5 and 6 to make certain the adjustment does not affect the sensitivity on these channels.

140. LINEARITY AND SIZE ADJUSTMENTS

Turn the color control fully counterclockwise to eliminate all color from the screen. Select a black-and-white transmission in the normal manner and make sure that the linearity of the picture is correct. Any readjustment of linearity and size controls will affect dynamic convergence voltages. (Over-scanning also affects convergence.) Check the horizontal oscillator for proper adjustment because later adjustments will affect convergence.

141. HIGH-VOLTAGE SETUP

Using a high-voltage probe and a vacuum-tube voltmeter, adjust the voltage regulator control for a 20-kv reading at the cathode of the high-voltage rectifier. With the meter still connected, adjust the brightness control from low-level to high-level brightness. There should be no appreciable change in voltage. If the voltage does vary, readjust the voltage regulator control.

142. COLOR PURITY ADJUSTMENTS

a. Turn the contrast control to its minimum position to remove the picture signal, and adjust the brightness control for maximum brightness. Turn the red screen control (R108B) to its maximum position, and turn the blue and green screen controls (R109A and R109B) to their minimum positions. Turn the convergence magnets out for minimum effect on the electron beams. Rotate the purifying coil on the neck of the kinescope, and adjust the purifying and field-neutralizing controls to obtain the largest red area possible on the screen. Move the deflection yoke forward or backward to obtain a uniform red color over the entire screen. If a pure red field has not been obtained, readjust the purifying and field-neutralizing controls.

b. Check blue purity by turning the red and green kinescope screen grid controls to their minimum positions and the blue kinescope screen grid control to its maximum position. Check green purity by turning the red and blue kinescope screen grid controls to their minimum positions and the green control to its maximum position. If some contamination remains, it may be necessary to make a compromise adjustment of the purity magnets for the best results on all three fields.

143. SETTING THE KINESCOPE TO WHITE

With the color and contrast controls set to minimum, turn the brightness control to maximum and adjust the red, blue, and green screen controls for a low-brightness white.

144. CONVERGENCE ADJUSTMENTS

a. General Considerations

(1) Convergence adjustments are divided into two classes: static convergence adjustments and dynamic convergence adjustments. A uniform pattern covering the entire raster is necessary in making convergence adjustments. The pattern obtained from a dot-bar generator, white dots on a dark background, is satisfactory for use in adjusting convergence. When static convergence is proper, the dots in the center of the raster will be converged; all other dots may be misconverged. This misconvergence results from the fact that the beams must travel greater distances when scanning the sides, top, or bottom of the raster, causing them to converge before they reach the shadow mask.

(2) When dc convergence is obtained, parabolic-shaped signals, derived from the horizontal- and vertical-oscillator circuits, are added to the d-c convergence voltage so that the voltage at the convergence electrode is increased as the beam is deflected away from the center of the raster.

(3) Dc convergence is achieved by adjusting the dc potential applied to the convergence electrode and by adjusting the three beam-positioning magnets over the three electron guns. Dynamic convergence is obtained by adjusting the vertical dynamic convergence shape and amplitude controls (R141B, R142B, R143B and R141A, 142A, 143A) and the horizontal dynamical convergence phase and amplitude controls (L122, L123, L124, and L112, L113, L114).

b. Dot-Generator Adjustment. Proper adjustment of the dot generator by means of horizontal and vertical controls produces dots approximately one-half inch apart. Set the brightness and contrast controls to a position which prevents "blooming" of the dot pattern.

c. Initial Receiver Adjustment.

(1) Set the horizontal dynamic amplitude controls to minimum. Set the vertical dynamic amplitude and shape controls to minimum.

(2) Turn the beam-positioning magnets out to the edge of the neck shield. Adjust the dc convergence control for optimum dot convergence in the center of the raster.

(3) With the dc convergence control set for optimum white in the center dots, adjust the beam-positioning magnets for perfect convergence in the center of the raster.

(4) If greater adjustment range is needed, remove the beam-positioning magnets from the shield and insert the opposite end of the magnets into the shield.

d. Dynamic Convergence Adjustment. Vertical and horizontal dynamic convergence adjustments provide correct overlap of the dot-generator pattern at the top, bottom, and sides of the raster. Horizontal and vertical dynamic controls interact, and the adjustment of one may affect the adjustment of the others. It is best to begin by adjusting vertical dynamic convergence.

e. Vertical Dynamic Convergence. Adjust the vertical dynamic shape control until the displacement of the dots at the extreme top and bottom of the raster is equal. Adjust the vertical dynamic convergence amplitude control until all dots along a vertical line through the center of the raster are equally displaced. When this condition is obtained, adjust the dc convergence control to converge the dots on the vertical line.

f. Horizontal Dynamic Convergence. Adjust the horizontal dynamic phase control until the extreme left and right center dots are equally displaced. Adjust the horizontal amplitude control until all dots along a horizontal line through the center of the raster are equally displaced. Adjust the dc convergence control to converge the dots on the horizontal center line. In some tubes, purity is improved if the dots are converged before purity adjustments are made. If purity adjustments are made after converging the dots, the convergence procedure must be repeated. When this is accomplished, disconnect the dot-bar generator.

145. WHITE ADJUSTMENT

a. Set the color and contrast controls to minimum.

b. Set the brightness control to maximum.

c. Adjust the red, blue, and green kinescope screen grid controls to a low brightness white. The "color" of the white should be similar to that produced by a low-brightness setting on a standard black-and-white kinescope.

146. HIGHLIGHT ADJUSTMENT

a. With the brightness control still fully clockwise, turn the contrast control to midposition.

b. Tune in a black-and-white picture or the dot-bar generator pattern.

c. Adjust the blue and green gain controls until the white described in paragraph 144c appears on the highlights in the picture.

147. LOWLIGHT ADJUSTMENT

With the contrast control at midposition, reduce the brightness with the brightness control. Adjust the blue and green background controls for equal white on the lowlights in the picture. With the brightness control at midposition, vary the contrast control from highlight to lowlight. If the white is not identical to that described in paragraph 144c, repeat the procedures in paragraphs 145 and 146.

Section III. COLOR TELEVISION SERVICING

148. INTRODUCTION

The servicing of a color television receiver involves more circuits and more complex problems than does the servicing of a monochrome receiver. Servicing problems can be simplified, however, if good troubleshooting procedures are followed. When isolating trouble in a color television receiver, it must be remembered that the receiver is basically a reproducer of black-and-white pictures with certain additional circuits devoted to color. In locating trouble, then, the first step would be to check the reception of black-and-white transmission.

149. BLACK AND WHITE RECEPTION

a. If scenes can be properly reproduced in black and white, it is a good indication that the following circuits are operating properly: high- and low-voltage power supplies, horizontal and vertical synchronization, sound i.f. and audio circuits, the second video amplifier, agc circuits, convergence circuits, the color killer, the horizontal blanking amplifier, horizontal and vertical deflection, the kinescope and kinescope controls. The rf tuner, picture i.f. circuits, and first video amplifier may effect color reception without noticeably affecting black and white reception.

b. Some general operating defects of monochrome reception are common to both color and monochrome receivers. For example: no picture, no sound, no brightness, and distorted picture. However, some defects found only in color receivers may be detected during monochrome reception on a color receiver. For example: color fringing which indicates misconvergence, and color shading which indicates impurity.

150. CONVERGENCE AND FOCUS TROUBLES

a. If the electron beams will not converge in the center of the raster, check the convergence voltage. At one end of the d-c convergence control range, the blue dot appears at the top of the dot trio while at the other end of the control range, the blue dot appears at the bottom of the dot trio. If the blue dot remains on top at all settings of the dc convergence control, the convergence voltage is too high. Check the setting of the phase control and the dynamic convergence circuits. Improper convergence will cause the black-and-white picture to appear blurry. (The blur is the result of several images that are not entirely superimposed.)

b. If the electron beams converge in the center of the raster but not on the sides, check the horizontal dynamic voltages by rotating the horizontal amplitude control. If this convergence voltage is present but has insufficient amplitude, check the peaking of the convergence amplifier circuits. A malfunction in the horizontal deflection or horizontal oscillator circuits also will affect the convergence voltage.

c. If the beams converge on one side of the screen before the other, recheck the horizontal phasing adjustments. Check the convergence amplifier tube and the horizontal output amplifier tube in addition to the phase coil adjustment.

d. If the beams converge on the sides but not at the top and bottom of the screen, adjust the vertical amplitude and shape controls. A fault in the vertical output stage can also vary the convergence voltages.

e. If the convergence voltages are correct but the beams cannot be made to converge by adjusting the dc convergence control, replace the kinescope and/or the convergence yoke.

f. Improper convergence may be caused by a fault in the matrix section resulting in poor frequency response of one video stage only. This improper convergence appears on the kinescope as a fringe of one color around the white dots of a convergence pattern. Check for peaking and proper response in the color adder section corresponding to the fringe color.

g. Low emission from one of the electron guns may cause an effect similar to the trouble outlined in subparagraph f. The beam from the defective gun will defocus and bloom at the screen, causing a color fringe around the convergence pattern dots. Before replacing the kinescope, check the kinescope voltages. If the kinescope voltages are not correct, adjust them as previously outlined. If the voltages are correct, replace the kinescope.

h. If an abrupt shift in convergence is noted, make sure that the high-voltage regulator circuit is operating properly. A shift in high voltage will shift convergence voltages.

151. UNIFORM WHITE OR GRAY SCALE

a. General. While viewing a black-and-white picture, it should be possible to vary the brightness control from a high to a low setting without altering the color of white or gray. In other words, after the correct white is obtained on the raster, there should be no color contamination of the highlights or lowlights in a black-and-white picture. If such a condition does not exist, follow the adjustment procedures described in the following subparagraphs.

b. Highlight Adjustments. With the brightness control turned fully clockwise, set the contrast control to midposition. Tune in a black-and-white picture or a dot-bar generator pattern. Adjust the blue and green background controls until a white of the same color as the raster appears on the high-brightness highlights in the picture. If the desired result cannot be obtained, the trouble is in the adder circuit which controls the complementary hue of color shading on the face of the kinescope. For example, if the kinescope field is magenta, the green adder circuit is defective because green is the complement of magenta. Before troubleshooting the adder circuits, make sure that the raster is normal and that video drive is not applied to the kinescope grids.

c. Lowlight Adjustments. With the contrast control still at midposition, adjust the brightness control for a reduced value. Adjust the blue and green background controls until the low lights in the picture are matched. Repeat the highlight and lowlight adjustments until the highlights and lowlights are matched.

152. CHECKING COLOR RECEPTION

Color reception faults fall into three general categories: no color, no color lock (synchronization), and improper color rendition. These faults can be quickly located because the circuits in which they occur are few in number.

153. FAULTS RESULTING IN NO COLOR

Before looking for tube or component failures, make sure that the set is properly adjusted to receive color and that the channel selected is transmitting a color program. If the set is properly tuned, check for proper antenna operation. A portable antenna will usually be sufficient to check color signal reception. Another method of checking the receiver is to set the color control fully clockwise and the color killer threshold fully counterclockwise. If color signals are being received, color snow and beat interference will appear on the face of the kinescope, indicating a faulty antenna.

154. ANTENNA CONSIDERATIONS

If the preceding checks indicate that color signals are being received, check the antenna in the following manner. Rotate the antenna to ensure that it is properly oriented. Broadband antennas should be used in preference to high-gain types, since high-gain antennas are likely to have limited band-width. Do not connect a color receiver to an antenna used by another receiver. If separate antennas are impractical, use low-capacitance switches to switch from one receiver to another. Resistance pads (300 to 1000 ohms) may be connected to the tuner input terminals if an impedance mismatch exists between the antenna cabling and the receiver input.

155. RECEIVER CONSIDERATIONS

a. If there is no color when the color control is set fully clockwise and the color threshold fully counterclockwise, check the color circuits. Certain checks can be made using only the transmitted color signal; however, a color-bar generator is more suitable for color signal circuit analysis.

b. Loss of color can usually be traced to the bandpass amplifier, burst keyer, burst amplifier, color killer, or 3.58-mc oscillator circuits. The burst keyer, burst amplifier, and color killer do not pass chrominance information but act to control the passage of the chrominance signals through the bandpass amplifier. The 3.58-mc burst signal must pass through the burst keyer and burst amplifier if the color killer is to be biased enough to be cut off and allow passage of chrominance signals through the bandpass amplifier. The 3.58-mc oscillator must be operative, or the demodulators will not operate properly.

156. FAULTS RESULTING IN NO COLOR LOCK

No color lock is a condition in which color is present in the picture but appears only as bars moving horizontally and vertically across the screen. When this condition exists, check the burst keyer, the burst amplifier, and their associated circuits. If the color bands are few in number, it indicates that the 3.58-mc oscillator is slightly off frequency.

157. FAULTS RESULTING IN IMPROPER COLOR RENDITION

a. Color involves hue, saturation, and brightness. A change in any one of these characteristics will cause improper color rendition. Since it has already been determined that black and white reception is good, the brightness component of the color signal must be normal. Thus, hue and saturation are the characteristics to be considered.

b. When all hues are present but appear improperly in the picture, the phase relationship between the burst and the 3.58-mc reference signal is incorrect. This condition usually results from improper operation of the chrominance or demodulator sections. In some cases only a slight alignment of the burst amplifier transformer may be all that is required.

c. Improper color saturation appears as a weak color, too strong a color, or no control of color. Circuits controlling the amplitude of the color signal usually cause such conditions; therefore, the circuits passing the chrominance and color difference signals should be checked. Check the bandpass amplifier and associated circuits first. If improper color saturation exists after all tubes and associated controls in the chrominance section have been checked, the receiver must be analyzed for defective components. Defective components may be found by following the receiver alignment procedure outlined in chapter 8.

158. INTERMEDIATE FREQUENCY DISTORTION

a. The most frequent cause of improper color rendition is malfunction of the color synchronization and demodulator sections. However, color rendition can be affected by faults in other parts of the receiver. Improper alignment of the rf and i.f. amplifiers can cause attenuation or loss of color information. Adjacent vertical edges of a sharp color transition appear as narrow bands of incorrect color if the high-video frequencies are lost or attenuated. The loss of high-video frequencies could go unnoticed in black-and-white reception.

b. Clipping in the picture i.f. or video sections can remove the burst reference, resulting in color synchronization trouble. Clipping in the i.f. stages can be checked by connecting the color-bar generator to the antenna input terminals and depressing the 60-cycle modulation button. With the color-bar generator properly adjusted, the color in the bars should not change or wash out. If they do, the signal is being clipped.

c. In a black-and-white transmission, reflections can cause poor picture synchronization. In a color receiver, the color synchronizing information may be cancelled by reflections and result in a complete loss of color synchronization.

d. A fault in the delay line in the luminance amplifier section will affect color. Approximately 1 microsecond of delay will cause an appreciable misregistration of chrominance information with the Y signal. Misregistration of chrominance information is indicated by the displacement of one or more color bars.

e. Faults in the power supply, such as a hum in the raster, present no additional problems in a color receiver. However, filament-cathode leakage in tubes in the video amplifier channels will produce color hum bars. Hum appears as green and magenta bars in the Q channel and as orange and cyan bars in the I channel.

159. MATRIX AND OUTPUT MALFUNCTIONS

Improper color rendition can also be caused by a defect in the matrix. The matrix can be checked by shorting any two kinescope grids to ground and observing the bar pattern on the face of the kinescope. The third and ninth bars of the blue matrix should have approximately the same brightness. The I gain control should be adjusted until this result is obtained. When checking the red matrix, the sixth bar should have the same brightness as the background. When checking the green matrix, the first and seventh bars should have the same brightness as the background. When these visual conditions are met, the matrix section is functioning normally. As improperly operating adder or output stage affects black-and-white reception as well as color reception.

Section IV. SUMMARY AND REVIEW

160. SUMMARY

a. The color-bar generator and the dot generator are test instruments used specifically for servicing color television receivers.

b. The color-bar generator is used to check color receiver operation and alignment.

c. The dot-bar generator is used for color receiver convergence and linearity adjustments.

d. An accurate sweep generator and crystal calibrator must be used in rf and i. f. amplifier alignment.

e. In checking high voltages in a color receiver, an accurate voltmeter and high-voltage probe must be used.

f. In servicing color television receivers, normal troubleshooting procedures are followed. Black-and-white reception is checked first.

g. A blurry picture is the result of improper convergence. The convergence voltage and the convergence amplifier should be checked.

h. There should be no change in the white or gray color when the brightness control is adjusted. If the white or gray color varies, the trouble may be in the adder circuit.

i. If a receiver reproduces a monochrome picture but not a color picture, the difficulty can usually be traced to the color synchronizing or demodulation phase-inversion circuits. Typical malfunctions are no color reproduction, no color synchronization or improper color rendition.

j. If there is no color, check the 3. 58-mc oscillator and the circuit from the bandpass amplifier to the demodulators.

k. Absence of color synchronization may be caused by the burst keyer, burst amplifier, or by an off-frequency 3. 58-mc oscillator.

l. Improper color rendition is usually caused by the bandpass amplifier, but it may be caused by improper alignment of the rf and i. f. amplifiers or by a defect in the matrix.

161. REVIEW QUESTIONS

a. What are the initial procedures in troubleshooting a color receiver?

b. If color is not reproduced by a video signal, in what sections of the receiver can the trouble be located?

c. How is color reproduction affected if the bandpass amplifier tube is weak?

d. If a receiver produces only values of orange and cyan, what signal is not reaching the matrix section?

e. The inability of the receiver to reproduce the hue of any color correctly indicates what fault in the 3. 58-mc oscillator signal?